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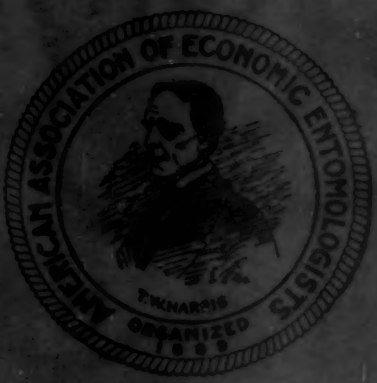


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VOL. 25 APRIL, 1932 NO. 2

## Proceedings of the 44th Annual Meeting of the American Association of Economic Entomologists (*Continued*)

*Wednesday Afternoon Session, December 20.*

The session convened at 1.45 p.m., President J. S. Houser presiding.

PRESIDENT J. S. HOUSER: The afternoon session will now come to order. The first paper will be by Mr. Roger C. Smith.

## THE CONTROL OF THE PEA APHID IN ALFALFA FIELDS WITH SPECIAL REFERENCE TO THE CHAIN DRAG[1]

By ROGER C. SMITH, *Kansas Agricultural Experiment Station*

ABSTRACT

This paper summarizes the history of the pea aphid (*Illinoia pisi* Kalt) as an alfalfa pest in Kansas, results of the attacks of this insect on alfalfa, and experiments on artificial control.

Nicotine sulphate sprays and dusts, use of harrows, field roller, cultipacker, and the brush drag did not give satisfactory control. Burning, while a theoretically correct control, is difficult, expensive, and of doubtful value. The use of Cyanogas flakes broadcasted in or at the margins of spots at about 30 lbs. or more to the acre, and the aphids then jarred to the ground, has given excellent results. Two aphid dozers, an original one, and one of Doctor Dudley's machines were tested for four seasons. Collections of 30 to 90% of the aphids have been made, depending on the height of the alfalfa. A new control implement, called a chain drag, has been devised. It has been used in only one outbreak where the infestation was reduced 50 or 60% by one treatment. The drag is inexpensive to build and operate. It is regarded as a promising control implement for this insect and possibly for some other insect pests occurring in alfalfa fields.

The pea aphid (*Illinoia pisi* Kalt) has become a major pest of alfalfa in Kansas.[2] While outbreaks have been local, this pest has occurred in some fields in destructive numbers in the eastern half of the state every

[1]Contribution No. 395, from the Department of Entomology.

[2]Smith, Roger C. and Davis, Edgar W. The Pea Aphid as an Alfalfa Pest in Kansas. Jour. Agr. Res. 1926. 33 (No. 1): 47–57. Bibl.

spring, beginning with 1921. The aphid first becomes apparent in early March, while the peak of damage occurred from the middle of April to about the middle of May. This insect lives during the entire season in alfalfa fields, overwintering there either as eggs or nymphs.

An infestation can be detected, even from a distance, by the lighter green color and bunchy growth of infested spots in fields (Pl. 2, Fig. 2). The aphids cluster on the new growth (Pl. 2, Fig. 1), sometimes in very large numbers. They fall to the ground upon a slight jarring of the plants, but soon crawl back up on the plants. Often the alfalfa growth above ground is completely killed and, in severe infestations, the entire plant may be killed (Pl. 2, Fig. 5). The margins of the everwidening spots of dead or severely injured alfalfa plants constitute the chief infestation until the aphids scatter, by flight, over the entire field.

The only paper on the subject of control is an excellent summary of experiments by Packard and Campbell[3]. Their results, for the same methods, are practically identical with those given here. The writer, however, has never found, in Kansas, numbers of dead aphids which had been killed by the sun and heat. Fungous diseases have apparently been more important as a control factor in California than in Kansas where they are of much less importance than either parasites or predators. The cultural practices which were reported as promising in California are dependent largely upon irrigation. These cultural practices either cannot be applied in Kansas or offer no hope of control. Pasturing alfalfa in the winter in Kansas is not practiced.

EXPERIMENTS ON THE CONTROL OF THE PEA APHID IN ALFALFA IN KANSAS. The first attempt at control of pea aphids in alfalfa fields was

[3]Packard, C. M. and Campbell, Roy E. The Pea Aphid as an Alfalfa Pest in California. Journ. Econ. Ent. 1926. 19:752–761.

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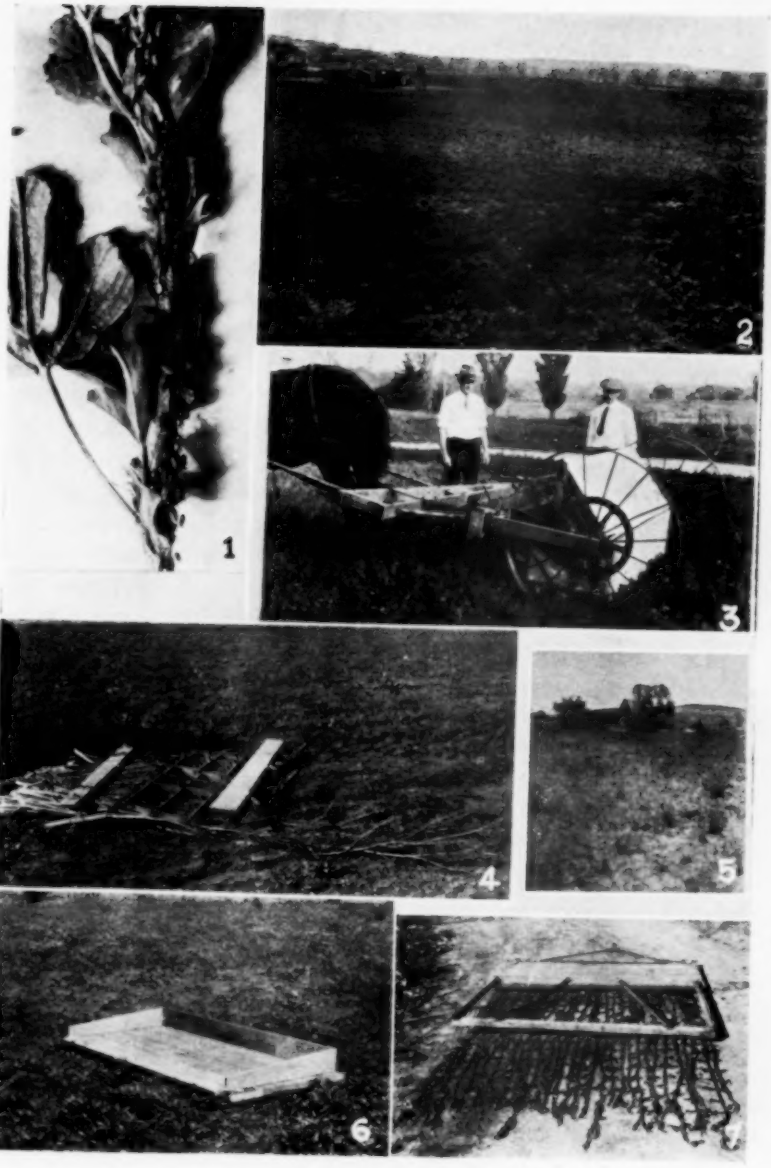
EXPLANATION OF PLATE 2

1, A stem of alfalfa showing a heavy infestation of the pea aphid; 2, A field of alfalfa April, 1928, showing lighter green spots where heavy infestations of the pea aphid were localized. Note the short, bunchy growth in the spots; 3, An aphidozer similar to Dr. J. E. Dudley's which was used until one of his was sent for tests of this method of control. Note there are strips of perforated tire tubing on the header reel to jar the aphids from the plants and to sweep them into the bed of the machine; 4, A brush drag, one of three used to test control with this device; 5, Bare areas in an alfalfa field showing how alfalfa plants may be killed by a heavy infestation of pea aphids. The aphids were heavily concentrated on the plants in the border of this spot for a width of ten or twenty feet; 6, The first chain drag made, to show the front margin of the drag and the hitch. The platform side boards were soon found to be unnecessary; 7, The experimental model chain drag, showing two series of drag chains.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made, by the writer, March 29, 1921, when a small area of heavily infested alfalfa was sprayed with "Black Leaf 40", 1½ pints, 7 lbs. of soap, to 150 gallons of water. About 800 gallons of spray mixture was applied to about two acres by means of a triplex power sprayer. Only about one percent of the aphids were killed. Later attempts at control with a 4% nicotine dust gave better results. The difficulties involved in spraying and variability of results make this control impractical.

Several efforts to control the aphids by harrowing the fields and by using a farm roller and cultipacker have always failed to give satisfactory results. Farmers have repeatedly reported satisfactory control by use of both a spring toothed and a spike toothed harrow, but the writer has failed to even approach control. Furthermore, harrowing so damages the plants, particularly the crowns and roots, as to make the method objectionable. The cultipacker and common field roller will, of course, mash some aphids, but due to uneveness of the ground, these implements offer no hope of successful control.

Cutting infested fields promptly upon appearance of the plant lice has both delayed and reduced the amount of the first crop. The aphids have sometimes concentrated on the new growth to the extent of killing the plants and further delaying the crop in others. It is, therefore, regarded as an unsatisfactory procedure.

Burning the dried alfalfa during the winter or early spring was found to be impractical. Very few fields have enough dry material on them to burn off properly. A small plot was covered with straw which was burned in the spring. However, the young shoots had started and the burning killed them. The growth was delayed. The cost of covering fields with straw and the damage to the young growth makes this theoretically correct method of control impossible or impractical. Packard and Campbell reported some results with several types of oil burners and stated that they may have some practical value for controlling this insect in alfalfa.

Dr. J. E. Dudley and his assistants designed a machine which he called an aphidozer[4] for pea aphid control. The writer built a similar machine during the early spring of 1924 (Pl. 2, Fig. 3). Doctor Dudley sent the writer one of his machines which was made by the Schaefer Manufacturing Company of Berlin, Wis. Both machines were used during several seasons and Dudley's machine was used in two large scale control efforts. Good results were obtained but since this type of machine can

[4]Dudley, J. E., Jr., Searls, Ed. M., and Weed, Alfred. Pea Aphid Investigations. Trans. 4th Internatl. Congress of Ent. 1928. 1929: 608–621.

be used best when the alfalfa is fairly tall, and since the aphids decline rapidly at that stage of growth, normally, there is some question as to how effective the aphidozer really was. From 30 to 90% of the aphids were collected, as shown by sweeping counts ahead of the machine and after it, a sufficient interval being allowed for the aphids to crawl up on the plants. The land should be level and the alfalfa about eight inches tall for best results. The chief objections to the aphidozer are its cost (initial cost of home-made one about $30.00 and the manufactured one around $100.00) and that it is ineffective for the small, bunchy growth (Pl. 2, Fig. 2) which is typical of early infested plants. The writer believes the aphidozer is the best control device available for infestations in tall alfalfa, which in Kansas occurs near the end of an outbreak the latter part of April or in early May. However, aphids do less damage to tall growth than to the early growth, and predators become controlling factors at that time.

The first attempts to control pea aphids in alfalfa with Cyanogas, applied by a horse-drawn potato duster and by hand dusters, were made May 5, 1923. These efforts gave 82 to 95% of aphids killed by actual count, though a little burning of leaves resulted. In 1924, a trailer was attached to a hand duster to hold the gas. Results were about as good without the trailer as with it, so it was discarded. Cyanogas flakes were broadcasted in spots at 30 lbs. to 90 lbs. to the acre and the aphids jarred from the plants by dragging a pole over the plants with equally good results. In later years, Cyanogas granules and Calcyanide have also been tried. Out of these tests has come a general plan for a successful method of control.

Use of Cyanogas Flakes and Granules. Repeated small scale tests have indicated that almost immediate control of these insects can be obtained with Cyanogas flakes sown by hand (gloved) or with a trowel at the rate of not less than 30 lbs. to the acre and the aphids are then immediately jarred to the ground. A kill of 85 to 90% may be obtained with this dosage and practically complete kills have been obtained with 60 to 80 lbs. to the acre in heavier growth. These sowings should be made near mid-day when the plants and the surface of the soil are dry and the air temperature about 70°F., or higher. This method, of course, is costly but it is not intended for entire fields. Only the breeding centers or "spots" in fields need be treated and, if found early enough, these areas are small. In later infestations (Pl. 2, Fig. 4), only the border of severely injured areas need to be treated. The amount of burning from the flakes has always been inconsequential and has not killed the plant. Packard and Campbell also found Cyanogas flakes

successful. The flakes are preferred because it is desirable for the material to sift through the plants to the ground where the aphids will come in contact with it. Burning of foliage may result if the material lodges on the leaves. The plant growth holds the gas somewhat so that a killing concentration may be obtained even in a fair breeze, but the application should be made, if possible, when there is little wind.

THE BRUSH DRAG. The brush drag method was early tried since this device has been repeatedly recommended by entomologists. The writer recognizes that there is considerable difference in brush drags but the drag shown in (Pl. 2, Fig. 4) is regarded as a good one. It has been impossible to obtain satisfactory control with three different brush drags. The ground was generally dragged crosswise at right angles, but never was anything approaching control obtained. Packard and Campbell likewise found the brush drag unsatisfactory. Young alfalfa on loose ground may be rather severely injured by thorough brush dragging.

Cutting alfalfa and then harrowing or brush dragging without removing the alfalfa was tried. The theory is, that the cut alfalfa will "ball up" under the harrow or drag and give the ground a harder rubbing. This, however, only rarely occurs because the alfalfa is generally too short to lodge under the harrow or drag. If cut when the alfalfa is tall enough to lodge under the drag, the stand is given fully as severe a setback as when attacked by the aphids.

THE CHAIN DRAG. After discarding the brush drag as a control device, a drag utilizing a series of chains was devised. The idea was obtained from seeing the covering chains of a grain drill. The first chain drag made in the spring of 1930 is shown in Pl. 2, Fig. 6. This was remodeled and the final experimental model is shown in Pl. 2, Fig. 7.

The experimental model of the chain drag consists of a platform of planks 6 ft. x 3 ft., held together by three iron runners beneath, to which the planks are bolted. The front ends of the outer two runners are recurved to form the hitch. The front edge of the platform is rounded and a sheet iron lip is nailed on, such that it extends above the top of the platform about one-half inch (Pl. 2, Fig. 6).

The chains used were old automobile tire chains of the heavier type, purchased from the junk yard at one cent a pound. The chains were cut in two and the treads cut in the middle, so that each tire chain made four drag chains. These were stapled on the bottom of the platform about two or three inches apart. A second series was stapled to a 2 x 4 which was held in place about four feet behind the platform by four angle-iron braces. This doubled the rubbing action because of the two series of chains.

The chain drag was pulled by two horses and the driver stood on the platform, well forward, to keep the front edge low. Infested alfalfa was first dragged in one direction, then cross dragged. The drag was not satisfactory in growths of alfalfa taller than about ten inches because the chains may be kept off the ground by the bent over growth. It was more effective for growths of three to six inches.

ACTION OF THE CHAIN DRAG. The aphids drop when the front edge of the platform strikes the infested alfalfa. Some of them drop on the platform and are kept from being brushed off by the sheet iron lip. After one or more rounds in the field, the aphids were swept off with a broom. The sweeping generally destroyed them or injured them so they did not crawl back on the plants. Almost as many aphids were thus gathered as were obtained by the aphidozer. This is a very definite, tangible destruction of surprisingly large numbers of the aphids, which the farmer can readily appreciate.

Some of the aphids drop, when the plant is jarred, in the clumps where they are protected by the growing stems and old stubble. The heavy weighted platform bends the stems over and exerts pressure on the growth such that some are crushed. These are the most difficult aphids to reach. The highest survival was from those dropping in the clumps, but they quickly crawled up on the plants and a second dragging destroyed some of them.

The remainder of the aphids drop free of the clumps. The chains dragging over them, roll them over and over, cover them up or injure them to such an extent that a high kill is made in this group. The clump of growth bends over and when the growth or stubble is fairly tall, the aphids on the far side of the clump escape the severe action of the chains to which the other three sides are subjected. Hence, cross dragging was found to be necessary. The chains follow all the uneven contour of the ground. They do not go round the clumps generally, but drag through them. The soil surface is actually harrowed by the action of the chains. Some observers have suggested dragging all alfalfa fields early in the spring to destroy the parent aphids and small weeds or grass as a general farm practice.

The alfalfa growth appeared injured after a double dragging, but it generally straightened up almost completely over night. The injury was confined to the leaves and stems, while the crowns and roots were not injured, as they were by the use of a disc or to a lesser extent by harrows.

The only large scale field test of this implement so far was made dur-

ing a severe outbreak in the region of Great Bend, Kansas, May, 1931[5]. Observers estimated that 50 to 60% of the plant lice were destroyed by the lengthwise and cross dragging. This was sufficient to stop the outbreak. Aphid enemies which for the most part survived the action of the chain drag so reduced the numbers of the aphids that the alfalfa began making a good growth. A farmer made a much wider chain drag without the platform. After using it and the experimental model, he dismantled his drag because he was convinced of the added value of the platform.

Conclusions concerning the value of this new implement for pea aphid control cannot yet be made, but the observations so far indicate that the chain drag is a useful control device. In the writer's opinion, it is the best mechanical device available for this insect control problem, except in tall alfalfa which ordinarily does not require attention. The calcium cyanide method is more quickly and more evidently effective for pea aphid control. It is also more costly. Most any farmer can readily make this drag of materials easily available at little or no cost. A drag 15 or more feet wide can be made, thus covering a large field rapidly.

The writer believes this drag may prove to have some value also in the control of some other alfalfa pests, such as the clover leaf weevil, cutworms, garden webworms, alfalfa caterpillars, and the green clover worms.

MR. C. J. SORENSON: I would like to ask how the calcium cyanide was applied?

MR. ROGER C. SMITH: We put on gloves and sowed it by hand.

MR. C. J. SORENSON: Did you try the powder?

MR. ROGER C. SMITH: In 1922 or 1923 we used the powder. It was not so good because we want something that will filter through the plants and fall to the ground so that the aphids will be brought in contact with the poison material on the ground.

Mr. C. J. SORENSON: On how large an acreage would that be?

Mr. ROGER C. SMITH: You apply this in the spring when the clumps are small. Pea aphids winter in small spots. A plot the size of several hundred square feet in area would be a large spot. We treat these very early in the spring. If you miss those aphids they spread over a large area.

PRESIDENT J. S. HOUSER: I would like to inquire how much consideration you give to plant and soil moisture conditions in applying calcium cyanide?

[5]The writer wishes to acknowledge the cooperation of Mr. Sherman Hoar, County Agent, at Great Bend, Kansas, in making these trials.

MR. ROGER C. SMITH: Plants must be dry and the surface of the soil must be moist. If the plants get wet there will be some burning but it is usually not severe. I have seen some damage but have never killed plants outright with calcium cyanide.

PRESIDENT J. S. HOUSER: The next paper is by Mr. M. A. Stewart.

## DISPERSAL OF THE STICKTIGHT FLEA OF HENS (*ECHIDNOPHAGA GALLINACEA* WESTW.)

By M. A. STEWART, *The Rice Institute, Houston, Texas*

ABSTRACT

The animals which may serve as dispersal agents of the sticktight flea of hens (*Echidnophaga gallinacea* Westw.) in North America and the hosts and distribution of this flea in the United States are considered in this paper.

*Echidnophaga gallinacea*, the sticktight flea of hens, was first described in 1875 by Westwood, who wrote in part as follows: "I have lately received from H. N. Moseley, Esq., one of the naturalists of the exploring ship Challenger, and also from my correspondent, Mr. Green of Colombo, Ceylon, numerous specimens of a minute species of flea, which attacks the domestic fowl in Ceylon, attaching itself firmly by its rostrum, in considerable numbers, around the eyes and neck of the birds, thus differing from the ordinary flea, which never fixes itself in such a manner as not to be able to disengage itself instantaneously, and also from the chigoe, which burrows into the flesh of its victim, human or quadruped...."

*Echidnophaga gallinacea* is most common, and hence of greatest economic importance, in this country in the southern states. As is well known, the injury resulting from its attack is most conspicuous in young chickens, which often die quickly when fairly heavily infested. These ecto-parasites cause death in adult birds when numerous, and when less numerous materially reduce the egg production, retard growth, and diminish the size. The occurrence of this flea is rather sporadic. Entire flocks of birds when placed in closely built houses, or when they roost or rest under large buildings, have been destroyed in a few week's time after the beginning of the infestation. In the South there is a considerable annual loss due to the attacks of this flea and it has been reported as being noticeably injurious to poultry as far north as Kansas. In 1925 there was an unprecedented outbreak of *E. gallinacea* throughout the southwestern United States. The loss of young chickens was especially great and egg production was reduced anywhere from five to

fifty per cent. It was estimated that the total loss during the spring season was in excess of one million dollars.

In the United States the sticktight flea has been collected in the following states: North Carolina, Louisana, Mississippi, South Carolina, Florida, Texas, Missouri, Virginia, Georgia, Alabama, New Mexico, New York, Minnesota, Montana, California, and Arizona.

The hosts of *Echidnophaga gallinacea* may be grouped into three classes. First, the normal hosts, domestic fowl, which are of economic importance; second, accidental hosts, which may or may not be of economic importance and which do not act as important agents of dispersal; and third, hosts which serve as efficient dispersal agents.

The host-parasite relationship of this flea and its normal host has been mentioned previously in this paper and has been described fully in a number of other papers.

The accidental hosts of the sticktight flea, which are not important dispersal agents but which in some instances may aid in maintaining an infestation, may be merely listed here. They are as follows: man, dogs, cats, horses, the domestic turkey (*Meleagris gallopava*), deer, burrowing owl (*Speotyto cunicularia hypogaea* Bonap.), Coopers hawk (*Accipiter cooperii* Bonap.), Swainson's hawk (*Buteo swainsoni* Bonap.), the ground squirrels *Citellus tereticaudus* and *C. spilosoma*, the white-footed mouse *Peromyscus maniculatus sonoriensis* Le Conte, and the coyote.

Of these accidental hosts, Swainson's hawk is of especial bionomic interest. Fisher writes of this bird as follows: "By preference it frequents the timber in the vicinity of streams, though often it is found far out on the prairie, where its only perch is the earth mound of some mammal, or some other slightly elevated knoll." Bendire writes, "I cannot recall a single instance where one of these birds visited a poultry yard.... From an economic point of view I consider it by far the most useful and beneficial of all of our hawks." With reference to this latter statement, we may state, in view of finding *Echidnophaga gallinacea* on this hawk, that it is quite possible that it does occasionally visit poultry yards.

In the group classified as agents of dispersal we find the following animals: Brewer's blackbird (*Euphagus* (*Scolecophagus*) *cyanocephalus* Wagl.), the English sparrow (*Passer domesticus domesticus* Linn.), the Texan bob-white (*Colinus virginianus texanus* Lawr.), and the Florida bob-white (*Colinus virginianus floridanus* Coues).

Brewer's blackbird is found in the Transition and Upper Sonoran zones from Manitoba and British Columbia southward in the mountains to Lower California and Guatemala, and from northwestern Minnesota

and Nebraska westward to the Pacific. Bailey writes of this bird as, "The dooryard blackbird of city and country. Often nests in oaks beside ranch houses and lords it over barnyard fowls with great airs of proprietorship." Obviously the habits of this blackbird are such as to make it an efficient dispersal agent of the sticktight flea of hens.

The habits of the English sparrow are sufficiently well known to make it unnecessary to describe them here. These habits admirably fit the bird as a dispersal agent of the flea under consideration. Ewing has previously shown this sparrow to be guilty of disseminating the chicken mite (*Dermanyssus gallinae* Redi). This new charge against the English sparrow makes its control all the more desirable.

The Texan bob-white is probably an efficient disseminating agent of *Echidnophaga gallinacea* by virtue of the fact that it often becomes sufficiently tame to feed with chickens in the barnyard. Bailey writes, "At San Antonio, Texas, Mr. Attwater says the quail often come close to his ranch and lay eggs in hens' nests, perhaps on account of the protection afforded against snakes." This bird is found in the Upper and Lower Sonoran zones from western Kansas south through Texas to Nuevo Leon and Central Tamaulpas, Mexico.

The Florida bob-white, which is found in Florida, except for the extreme northern part, is probably not as efficient as a dispersal agent of the sticktight flea as is the Texan bob-white. This bird is especially numerous in patches of cowpeas on old plantations.

Quite possibly the bob-white, *Colinus virginianus virginianus* Linn., also acts as a disseminating agent of *E. gallinacea* but as yet there is no record of it being collected from this bird. However, it probably would not be a very efficient vector. This bob-white is found in the Upper Sonoran and southern half of the Transition zones of eastern North America from South Dakota, southern Minnesota, southern Ontario, and southwestern Maine southward to eastern and northern Texas, the Gulf coast, and northern Florida, and westward to eastern Colorado. It has been introduced into central Colorado, New Mexico, Utah, Idaho, California, Oregon, and Washington.

It would be unwise, of course, under anything but extreme conditions, to take direct control measures against any of these dispersal agents, with the exception of the English sparrow. However, it is well to bear in mind that these various birds are capable of initiating, maintaining, and spreading infestations of the sticktight flea and it is possible that when control measures must be directed against these hosts satisfactory methods, which will not jeopardize otherwise valuable birds, may be found through ecological research.

MR. F. G. HINMAN: I would like to ask if there is any difference in the number of fleas found on different species of fowl.

MR. M. A. STEWART: That depends on the degree of infestation. On a light or moderate infestation the greater number is found on young chickens. On heavy infestations they are found in almost equal quantities. If a heavy infestation occurs in places where there are no young chickens, they remain as a very heavy infestation on adults. The effects are more serious on young chickens than on adult fowls.

PRESIDENT J. S. HOUSER: We will now hear a paper by Messrs Stanley B. Freeborn and W. M. Regan.

## FLY SPRAYS FOR DAIRY COWS—A PROGRESS REPORT

By S. B. FREEBORN, *Associate Professor of Entomology*, and W. M. REGAN, *Professor of Animal Husbandry, University of California, Davis, California*

ABSTRACT

Fly sprays of petroleum oils carrying pyrethrum, pine oil, or both, designed to keep flies from dairy cows were tested for their efficiency. It was shown that all had approximately the same efficiency for the first hour but differed at subsequent intervals, pine oil increasing their efficiency in proportion to the amount applied.

Burning followed the use of oils having a viscosity lower than 40 seconds irrespective of the unsulfonated residue while oils with unsulfonated residues below 90 per cent were dangerous if used in oils of higher than 65 seconds viscosity.

The pyrexial point, defined as the environmental temperature above which cows could not maintain a normal body temperature, was determined for the experimental animals. The application of oil sprays lowered this pyrexial point approximately five degrees by impairing the small amount of cooling that takes place, through the action at the surface of the skin. The different sprays varied in their effects on this pyrexial point.

In 1925[1] and again in 1928[2] the writers reported on experiments carried on to determine the effects of flies and fly sprays on milk production. Three different types of fly sprays were used, (1) a bland white oil with 100 per cent unsulphonated residue and a viscosity of 105 seconds Saybolt, (2) a mixture of two parts of the above mentioned white oil with one part of household fly spray (kerosene and pyrethrum), and (3) a three per cent dilution of an emulsion made by emulsifying, by means of sodium hydroxide, equal parts of creosote and pine tar.

The net results of these trials indicated (1) an infestation of house

[1]The Relation of Flies and Fly Sprays to Milk Production, Freeborn, S. B., Regan, W. M., and Folger, A. H. 1925. Jour. Econ. Ent. *18:* 779–790.

[2]Idem, 1928, *21:* 494–501.

flies or horn flies produces no appreciable effects on the milk supply, (2) stable flies in numbers in excess of 10,000 per cow produce a loss of approximately nine per cent, but (3) the application of any of the fly sprays mentioned above increases the loss from stable fly infestation and produces a definite loss in cows held as controls without flies or infested with house or horn flies.

TABLE 1. CHARACTERISTICS OF THE SPRAYS TESTED

| Character | Boiling Range °F | Viscosity of blend S. U. 100 °F | Unsulphonated residue of blend | Toxics per gallon |
|---|---|---|---|---|
| Straight cut | 550–660 | 54 | 93 | ¾ lb. Pyrethrum |
| Blend | 379–690 | 40 | 86 | ½ lb. Pyrethrum + 3% Pine oil |
| Blend | 320–640 | 40 | 89 | ½ lb. Pyrethrum + 3% Pine oil |
| Blend | 316–757 | 36 | 63 | ⅓ lb. Pyrethrum + 4% Pine oil |

In the light of modern fly spray practise our previous experiments, mentioned above, were subjected to the criticism that we applied too much spray. In our trials we had no criteria as to the proper amount and had established it at the amount necessary to effect an average repellent efficiency of 80 per cent over a period of twenty-four hours. This standard required the application of approximately 250 cc of spray per 1,000 pound cow.

Although the writers have consistently advocated fly control by means of careful sanitation and have even found trapping of adult flies to be more advantageous than spraying for barn control, the enormous amounts that are spent by dairymen yearly for fly sprays somewhat justifies the continuation of this work with the present day products.

The present tendency in fly sprays is to use a petroleum oil base to which is added pyrethrum or pine oil or both. The repellent, and to some extent toxic action, of the pyrethrum and pine oil increases the efficiency of the oil and decreases the amount that is necessary to apply. In many cases commercial household spray is added to a base of heavier oil for the purpose of avoiding the burning or irritating action that would follow its use undiluted. Many claims have been made for the relative values of the unsaturates versus completely saturated oils, heavy versus light oils, and wide blends versus straight cuts or close blends.

We commenced our experiments early in May with an attempt to choose the most effective insecticides for further trials of their effects on the animals.

The sprays selected and their characteristics are shown in Table 1.

Animal husbandry authorities differ as to the function of fly sprays. Those who have given the most thought to the subject believe that the

TABLE 2. PERCENTAGE OF EFFICIENCY

| Spray | 20 cc per cow applied in barn | | 80 cc in barn | 40 cc in corral | |
|---|---|---|---|---|---|
| | During 1st hr. | At end of 24 hrs. | Avg. of first 5 hrs. | Avg. of first 5 hrs. | Avg. of first 8 hrs. |
| Straight cut... | 96.3 | 0 | 87 | 80 | 59 |
| Close blend.... | — | — | — | 85 | 70 |
| Medium blend. | 98.6 | 33.5 | 94.2 | 74.2 | 54 |
| Crude blend... | 92.0 | 0* | 94.6 | 73 | 53 |

*The crude blend for this trial contained only 2% pine oil.

chief function is to protect animals on scanty pasturage allowing them to feed undisturbed. Those who merely give the problem a passing thought are apt to believe that the prime function is to protect the animals and keep them quiet during milking time. Both are probably important but a spray which satisfied the former condition would at the same time fulfill the second requirement. It was a spray of this dual relationship that we sought.

Table 2 presents the results of trials in terms of the efficiency as compared with the average number of flies found on cows of the same breed and color subjected to the same conditions but unsprayed. Data obtained from trials of this sort are subject to many errors. For instance, counts made in corrals and on the range will vary markedly from counts made in a sheltered shed or barn; where horn flies are present, a very moderate infestation will include at least two hundred flies and inasmuch as this species is completely controlled by any of the sprays for periods of twelve hours or more, their presence on the controls gives an extremely favorable percentage for the spray under test. Fortunately at Davis, California, where our trials were carried on, this species is comparatively rare on dairy cattle and did not confuse our results but did cause some misunderstanding with our collaborators who were working in a horn fly area and consequently obtained more satisfactory results than we were able to show in our trials which were largely restricted to house and stable flies.

The results of the first trial with 20 cc of spray per cow applied in the barn show approximately the same efficiency for the first hour. Twenty cubic centimeters is approximately a complete coverage of a thousand

pound cow with a very light spray. Each fly alighting and remaining on the animal during the first hour was considered a positive. On each succeeding day the same animals were observed before spraying and the data obtained for the column denoting the efficiency at the end of twenty-four hours. At the end of 24 hours the straight cut oil with pyrethrum had lost all of its efficiency as had the crude blend spray containing pyrethrum and pine oil but the medium blend had retained nearly one-third its efficiency. This we have attributed to the pine oil bound in its oil base. The crude blend contained only 2 per cent pine oil for this test. For the ensuing trials it was increased to 4 per cent.

In the second set of trials, we attempted by applying an unusually large amount of spray (80 cc) to protect the animals over a period of five hours. Readings were made at the end of each hour after spraying. The straight cut with pyrethrum had lost more of its efficiency proportionally than had the two blends containing pine oil.

In the third trial the animals were confined in an open corral without shelter from wind or sun and sprayed with 40 cc each. Observations were made each hour. A comparison with the 80 cc column shows that the relatively heavy oil with pyrethrum (straight cut) was nearly as effective in amounts of only 40 cc at the end of five hours as it was with an 80 cc application. On the other hand, the medium and crude blends containing pine oil lost approximately 20 per cent of their efficiency when the dosage was reduced 50 per cent. This finding tends to substantiate laboratory tests showing that pine oil acts independently of the oil carriers, whereas the pyrethrum combines actively with the oil. The loss for eight hours merely accentuates the facts shown by the efficiency at five hours.

It is difficult to draw definite conclusions but it is safe to assume that pine oil adds to the effectiveness as a repellent particularly after the first hour; that it exercises its activity qualitatively and quantitatively as an agent independent of its oil carriers, that uniform distillation curves are desirable, and that the heavier bodied oils are superior to the lighter ones as carriers with the reservations noted below.

The question of repellent action is only half the picture however. Fully as important as the efficacy in repelling flies is the effect of the spray on the cow. The sulphonated residues or unsaturates in petroleum oils are themselves rather potent fly repellents but their inclusion is fraught with danger to the cows. In the same way household spray with its carrier of low boiling point is very effective for a short time but on account of its low viscosity and high penetration it is dangerous to the cows.

Without going into the details of the tests, which lack of space forbids, it would seem that the characteristics of the oil are extremely important from the standpoint of the welfare of the cows. A viscosity of 38 seconds was toxic even though the unsulphonated residue was nearly 100 per cent. On the other hand, an oil with a viscosity of 70 seconds was toxic in connection with a 90 per cent unsulphonated residue and safe with a 100 per cent unsulphonated residue. With a 100 per cent unsulphonated residue it is safe to go as high as 105 seconds viscosity providing excessive amounts are not used. In other words, an oil with a viscosity below 40 seconds is apt to burn the cow and one above 65 seconds may also burn if the unsulphonated residue is much below 90 per cent. The natural inference is that the oil of the higher viscosity holds the unsaturates on the body of the animal long enough to produce toxic effects while one of a lower viscosity, such as 50 seconds, allows for the volatilization of the unsaturates before serious damage is produced. In this connection it must be borne in mind that a wide blend made of a very light and a very heavy oil may give a viscosity reading within the safe range (40–65) but with the rapid volatilization of the lighter fraction, the residual oil left on the cow may have a much higher viscosity than the original blend in which case any percentage of unsaturates might prove dangerous. After all is said, however, the matter of application itself becomes of extreme importance. With a careful, uniform application where the spray does not wet the animal's skin but hangs in the hair, a mixture that violates all the precepts mentioned above, such as our crude cut blend, can be applied without injury. In the hands of the average milker, however, sprays of this type are fraught with danger.

In our previous studies we were forced to accept the weather as it came and rely on our control animals to evaluate the effects of temperature and humidity on the sprayed cows. For our present trials, however, we had available a psychrometric chamber capable of housing two cows over long periods of time where the temperature and humidity could be regulated and maintained at will over a wide range of conditions. In a set of experiments that are being reported elsewhere, it was found that each cow had a maximum environmental temperature known as the "pyrexial" point above which her thermo-regulatory devices failed to function efficiently with the result that respiration and body temperature rose almost immediately and milk production decreased after a lag of about two days. This "pyrexial" temperature varies slightly with different cows and is but little affected by the relative humidity. Studies are now in progress regarding the effect of saturation deficiencies.

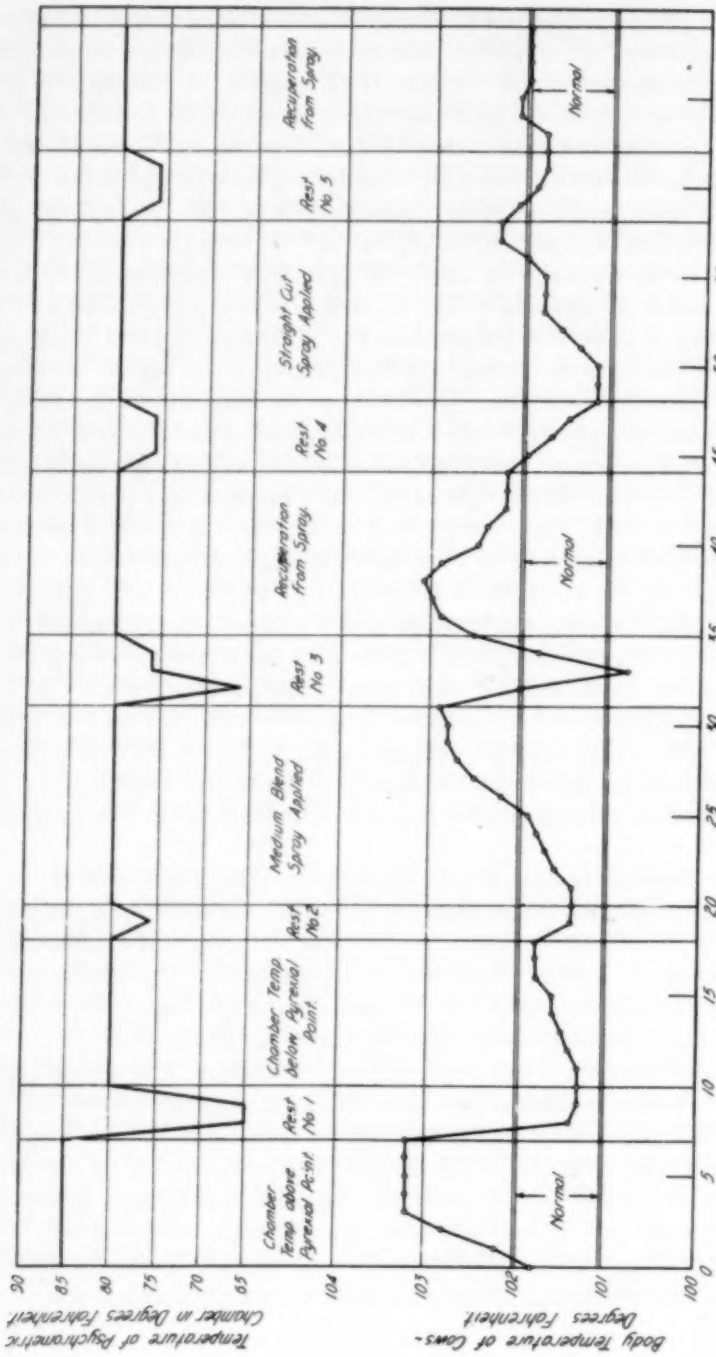



FIG. 5—Graph Showing Temperatures and Other Data

We selected two producing cows of the same lactation period and after holding them at various temperatures for periods of ten days each, during which the relative humidity was held at 68 per cent, determined that they functioned normally at 80°F. However their pyrexial point above which their temperature and respiration increased and the milk production decreased was between that and 85°F. After this trial at 85°F the temperature of the chamber was brought back to 80°F and the cows again regained their normal functions. (See Fig. 5.) At this time we sprayed each with 40 cc of the medium blend spray daily for ten days. Their reactions approximated the clinical picture produced at 85°F or, in other words, their pyrexial point had been lowered approximately five degrees by the action of the spray. Their respiration and body temperature rose to nearly the same level as the 85° trial and their milk production decreased at the same time. After ten days of spraying they were washed, held at the same temperature (80°F) and after a period of four days, that we interpret as recovery, the curves for respiration, body temperature, and milk production again returned to normalcy.

Following ten days of rest at 80°F without any spraying, they were then sprayed with the straight cut oil which contains pyrethrum but no pine oil. Their body temperatures rose slowly reaching 102° on the eighth and 102.3° on the ninth and tenth days of the trial. During the recuperation period the temperatures rose to slightly above normal for two days but recovery was relatively rapid.

On the basis of our observations of these trials we advance the tentative assumptions that oil sprays exercise an effect on the skin of the cows that interferes with the cooling function of the skin. When the environmental temperature is as close to the pyrexial point of the animal as 80°F was in our trials, the additional cooling produced by evaporation from the skin is required to maintain a normal temperature in the trial animal. However, if this auxiliary cooling function is hampered (physiologically or mechanically?) by the application of oil sprays the respiratory cooling apparatus is not adequate to maintain the normal body temperature and fever results. That the application of oil produces no systemic toxins which might account for the abnormal temperatures is shown strikingly in Rest Period 3 where the environmental temperature was inadvertantly reduced to 66°F immediately after the trial with the medium blend oil which had produced nearly a degree of fever. The temperature of the animals dropped to sub-normal almost immediately.

After each spray trial the animals were washed thoroughly with soap and water but in spite of this precaution the temperature rose again after the rest period at 76°F when the animals were subjected to 80°F

again. This has indicated to us that the oil produces a definite physiological effect on the skin which impairs its ability to aid in maintaining the body temperature.

The difference between the effect of the medium blend oil and the straight cut may be caused by one of several factors. The viscosity and the unsulphonated residue of the medium blend are both low enough to be close to the threshold of tolerance. Experiments now under way may throw more light on the question.

From a practical standpoint either of these sprays is acceptable except under conditions of prolonged, sustained heat waves where the temperature remains at or above 80°F. Under all lower temperatures the thermo-regulatory apparatus of the animal functions adequately without the aid of the cooling power of the skin which appears to be the only function impaired by the application of oil sprays.

MR. M. A. STEWART: Have you had any experience with the horn fly?

MR. S. B. FREEBORN: We used horn flies in cages with animals in 1928 but could not produce a loss of milk production greater than 1.4 per cent.

PRESIDENT J. S. HOUSER: The next paper is by J. R. Parker and R. L. Shotwell.

## DEVASTATION OF A LARGE AREA BY THE DIFFERENTIAL AND THE TWO-STRIPED GRASSHOPPERS

By J. R. PARKER and R. L. SHOTWELL, *Bureau of Entomology, U. S. Department of Agriculture*

ABSTRACT

During the summer of 1931 grasshoppers (*Melanoplus bivittatus* and *M. differentialis*) destroyed 75 per cent of the crops over an area 17,000 square miles in extent and 25 per cent of the crops over an additional 13,000 square miles. Commercially made poisoned bran mash gave good results. Air-planes were used successfully and economically in scattering grasshopper bait in corn fields. Maximum feeding on poisoned bran mash took place most commonly at air temperatures of 75 to 85°.

During the spring and summer of 1931 there occurred in south-central South Dakota and northeastern Nebraska the most serious grasshopper outbreak recorded in the United States since the days of the Rocky Mountain locust. The almost complete destruction of all cultivated crops over an area of thousands of square miles in extent ranks this outbreak as one of the most serious insect plagues which has ever confronted the farmers of the West.

AREA INVOLVED. The zone of heaviest infestation included all or parts of the following counties in South Dakota—Sully, Hyde, Hand, Stanley, Hughes, Jackson, Jones, Lyman, Buffalo, Jerauld, Mellette, Brule, Aurora, Tripp, Douglass, Gregory, Charles Mix, Bon Homme, Clay, and Union; and parts of the following counties in Nebraska—Keyopaha, Boyd, Knox, Cedar, Dixon, Dakota, Brown, Rock, and Holt. This is an area of approximately 17,000 square miles in which about 7,500 square miles, or 4,800,000 acres, were in crops. At least 75 per cent of all cultivated crops was destroyed by grasshoppers. The writers know of no instance recorded in the United States during the last 50 years where all cultivated crops over such a large area were so nearly wiped out by insects.

Surrounding the zone of heaviest infestation in South Dakota and Nebraska and pushing down into western Iowa was an additional area of less severe damage, containing approximately 13,000 square miles of which about 6,500 square miles, or 4,160,000 acres, were in crops. In this secondary zone crop losses averaged at least 25 per cent.

SPECIES CONCERNED. The two-striped grasshopper (*Melanoplus bivittatus* Say) and the differential grasshopper (*Melanoplus differentialis* Thos.) were responsible for at least 95 per cent of the damage done to crops in the devastated area. They were present in very nearly equal numbers with *differentialis* slightly predominating. While both species have been considered in the past as of great economic importance in localized outbreaks, there is no previous record of their occurring in such enormous numbers over so large an area. Furthermore these species have been generally described in entomological papers as large, clumsy grasshoppers with feeble powers of flight and seldom moving far from the spot where they hatch. In the present outbreak they appeared more slender of body, remarkably active, and strong in flight, and displayed distinct migratory tendencies both in the nymphal and adult stages, as will be brought out more fully elsewhere in this paper.

SEASONAL DAMAGE AND LIFE-HISTORY NOTES. Eggs of *bivittatus* started hatching in numbers in South Dakota during the second week in May and the main hatch of *differentialis* started during the last week in May. Intermittent hatching of *bivittatus* continued to July 1 and of *differentialis* to July 10. On May 26, first and second instar nymphs of *bivittatus* and first instar nymphs of *differentialis* were already leaving their hatching grounds in sod land adjacent to cultivated fields and were injuring small grains, alfalfa, and other tame hay crops. Destruction of these crops and of flax continued throughout the nymphal period of both species. Corn was only slightly damaged during this period and

swarms of nymphs were observed migrating through corn on their way to young barley, which they seemed to prefer above all other crops.

Adults of *bivittatus* were common on June 15 whereas no adults of *differentialis* were observed until the last few days of June, when an enormous number of nymphs transformed to the winged stage. By this time small grains, flax, and tame hay were almost completely destroyed and no longer afforded sufficient food for the voracious newly transformed adult grasshoppers or for the young grasshoppers still in the nymphal stage. Flying and hopping swarms now moved toward the nearest corn crops which were devoured in a surprisingly short time. In one instance actually observed a 400-acre field of corn in which the plants were from 2 to 3 feet in height on June 29 was reduced to bare ground by July 2.

The amount of vegetation consumed by grasshoppers during the first two weeks in July was beyond belief. Hundreds of cornfields in which the crop had stood head high were so completely cleaned of vegetation that strangers doubted whether a crop had been planted. In thousands of other fields a few scattered stripped stalks remained as the only evidence of a once promising corn crop. While corn was the only cultivated crop that offered succulent food in large quantities, other vegetation also was attacked. Native trees and bushes along creek and river bottoms were often entirely defoliated. Swarms of grasshoppers clustered on the sides of farm houses, destroyed gardens, ate the leaves, fruit, and bark in orchard and small fruit plantings and stripped the leaves from ornamental and shelter-belt trees. Cemeteries were invaded and even the needles on spruce and other evergreens were eaten by the hungry grasshoppers.

After the 15th of July destruction of corn proceeded at a less rapid pace but swarms of grasshoppers continued to move from one field to another completing their work of destruction. Cornfields far removed from small grain or tame hay land were the last to be attacked and in some cases escaped with slight losses. During August grasshoppers were no longer concentrated so heavily in cornfields but were scattered in rank weeds and grasses along creek bottoms and in succulent Russian thistles, which were now growing in all of the fields where small grains had been destroyed. Cornfields in which the crop had been only partially destroyed before August 1 still harbored large numbers of grasshoppers now concerned with laying their eggs in adjacent sod land. Feeding in such fields continued on a much decreased scale until fall, but was generally sufficient to ruin the ears and to strip most of the leaves. By September, one could ride for a hundred miles through

the heart of the devastated region and not see a crop of any kind that was worth harvesting save for an occasional field of sorghum which is immune to grasshopper attacks after it has attained a height of 6 to 8 inches. In some sections rather large acreages of the various sorghums, especially kaffir and cane, were planted on land where corn and been destroyed by grasshoppers early in the season. These crops produced good yields of fodder and for many farmers was the only "roughage" available for wintering livestock.

*M. bivittatus* was laying eggs in quantity by July 15 and *differentialis* by August 1. Egg-laying continued well into October and a few females were still ovipositing in early November.

## Control

Poisoned-bran mash. The principal method of control attempted was the use of poisoned-bran mash. It must be admitted at the start that although thousands of tons of this material were used, crops were almost a total loss in the more heavily infested areas. The failure to save even a fair percentage of the crops attacked does not mean that this method of control should be discarded. Poisoned-bran mash containing a sufficient quantity of arsenic gave excellent kills wherever properly applied, but failed to save crops because it was not obtainable in sufficient quantities at the right time. When it became apparent that control by individual effort was out of the question, county authorities were appealed to and in most cases responded by ordering large quantities of the materials used in making grasshopper bait. Firms dealing with these supplies were flooded with orders, and as a result shipments were either delayed or delivered only in part on the dates promised. To meet this situation county officials limited the material issued to an individual land owner in many cases to an amount that would make 200 pounds of ready-to-use bait for each 160 acres of cropped land. This amount was entirely inadequate and as a result destruction of crops continued at a rapid pace. A more sound policy from an entomological and economic standpoint would have been to furnish materials sufficient to properly treat a block of adjoining farms, but to concentrate materials bought with public funds in one district when farmers throughout the county were demanding their share was impossible from a practical point of view.

By the time supplies were coming in sufficient amounts, small grains, flax, and tame hay had been largely destroyed and great swarms of grasshoppers, the majority of them winged, were invading corn which up to this time had been only slightly damaged. Efforts were now made to

save the large acreage of this important crop. Fields treated with bran mash several times on successive days had scores and often hundreds of dead grasshoppers at the base of each cornstalk, but for every one killed it seemed that a dozen were ready to take its place. It is a slow and tedious process to scatter grasshopper bait by hand over a large field of tall corn, and after one or two attempts to check the invading armies of grasshoppers the majority of farmers gave up in despair.

The almost total loss of crops in spite of the use of unusually large quantities of poisoned-bran mash should serve as an object lesson in future attempts to control grasshoppers. Two main points stand out as reasons for the present failure: (1) Disastrous delays in obtaining supplies because orders were not placed until grasshoppers were already seriously injuring crops; (2) inability to fight grasshoppers successfully and economically after they have reached the winged stage.

The use of poisoned-bran mash is still believed to be the best available method of fighting grasshoppers. It is further believed that if communities can be aroused to concerted action and sufficient supplies are available when needed, young grasshoppers can be largely killed off on the hatching grounds and while they are attempting to invade crops and that a very large percentage of the crops attacked can be saved.

It should be emphasized, in this connection, that the same amount of poisoned bran used when young grasshoppers are concentrated along headlands will be far more effective than when they have increased in size and are dispersed over an entire field. Fighting grasshoppers before or at the time they are invading crops is one of the essentials of a successful campaign.

In explaining the failure to control grasshoppers and in calling attention to the factors essential for success there is no intention to criticise or blame the State entomological leaders who were in charge. As a matter of fact, they strongly advocated, through the press and at meetings of farmers held before grasshoppers had hatched, the same method and practice of grasshopper control that have been stressed in this paper. But local conditions were such that few of their recommendations could be followed even when farmers desired to do so. Counties within the grasshopper area, almost without exception, were without county agents, and this made it extremely difficult for communities to organize in a united effort to control grasshoppers over an entire locality. Lack of money prevented many farmers from cooperating with their neighbors in control operations. County governments were also short of funds and would not appropriate money for grasshopper control until damaged crops proved that an emergency existed. This in turn caused serious

delays in obtaining supplies. Hampered by lack of funds and with no county agents to work with, the State leaders were called upon to face a grasshopper outbreak so severe that it would have seriously threatened the success of the most generously financed and completely organized control campaign imaginable.

COMMERCIALLY-MADE POISONED-BRAN MASH. The manufacture of poisoned bran mash by large milling concerns was a new development in grasshopper control that originated during this outbreak. Commercially-made poisoned-bran mash comes to the farmer as a dry product containing bran, arsenic, and molasses or other desired materials, in the proportions that have been specified by those in charge of the campaign. Only water needs to be added to make it ready for use. It has a number of advantages over the home-mixed product. More uniform mixing of the ingredients is obtained by the use of milling machinery than can ever be accomplished by hand methods, and the dangers that accompany the handling of arsenic by hundreds of inexperienced farmers are partly eliminated. One concern impregnated the mixture of dry bran and arsenic with hot molasses which seemed to give the manufactured product a richer and more lasting odor than was ever obtained with cold molasses in the home-mixed material. Labor-saving devices, ability to buy materials in large quantities, and the desire to keep their plants operating during the slack season enabled feed mills to deliver the manufactured product at almost the same price that many counties were paying for ingredients alone. Where such was the case the counties were saved the expense of operating mixing stations and the troubles incidental to ordering materials from several different firms. One concern sold a product composed by weight of 80 per cent bran, 15 per cent molasses, and 5 per cent arsenic for $22.50 per ton at the mill. Few counties could buy the ingredients and make their own bait at this price unless they bought molasses in tank-car lots and arsenic in carload lots direct from the smelter. Another important advantage of the commercially made poisoned-bran mash is that it can be made in carload lots on very short notice, a feature which has been sufficiently stressed in this paper to need no further comment. It is believed that commercially made poisoned-bran mash will be a factor in all large grasshopper outbreaks of the future and that when honestly made according to prescribed specifications its use will prove to be a decided advance in grasshopper control.

AIRPLANE SCATTERING OF POISONED-BRAN MASH. To the best of the author's knowledge the first scattering of poisoned-bran mash by airplane was done by Mr. John Halgrimson of Winner, South Dakota, during the summer of 1930. He was enthusiastic about the results and

arrangements were made for him to treat a heavily infested 240-acre cornfield at Winner on July 13, 1931. A ton of bait (dry weight) was applied in 2 hours and 40 minutes, which included stops for reloading at a landing field adjacent to the cornfield. Mr. Halgrimson flew the small cabin plane about 15 feet above the corn, and a helper sitting in the cabin door, and with one foot braced against a strut, shook the poisoned-bran mash from a sack held in his lap. The falling mash was caught in the back wash from the propeller, broken into individual flakes, and scattered very uniformly over a space about 20 feet in width. Charge for the plane was made at the prevailing price of $12.00 per hour, which made the cost of application 13.3 cents per acre. It is doubtful whether bran mash can be scattered in tall corn by any other method at so low a figure and certainly there is no method known at present by which it could be scattered so evenly or quickly. An excellent kill resulted from the treatment, but continued invasions of grasshoppers caused serious injury. Nevertheless enough corn was picked from this field to more than pay the cost of the treatment whereas adjacent fields were a total loss. Mr. Halgrimson also treated 200 acres of corn and an adjoining small alfalfa field on his brother's farm. Six applications were made at weekly intervals, 600 pounds (dry weight) being scattered each time. Flying time consumed for each treatment was 50 minutes, or a total of 5 hours. Allowing $12.00 per hour for flying and $25.00 per ton for poisoned-bran mash, the total cost was $105.00. As return on this investment 2,000 bushels of corn and 30 bushels of alfalfa seed were harvested while in surrounding fields not even the cornstalks remained as evidence of a crop. It is believed that with a larger plane equipped with a mechanical device to feed the bait uniformly into the propeller back wash, the cost of scattering could be reduced to at least 10 cents per acre. An outstanding feature of airplane scattering is that large acreages can be treated in a comparatively short time, advantage thus being taken of the optimum feeding period, which is seldom over three hours in any one day. Airplane scattering seems to be the logical method of treating large, uniformly infested areas which are difficult of access by wagon or truck and it should have an important place in future grasshopper control campaigns.

## Research Work

In cooperation with the South Dakota Experiment Station and Extension Service, further studies were made of the use of poisoned-bran mash and poisoned dusts, feeding habits, migratory movements, and flights.

POISONED BAITS AND DUSTS. In some preliminary tests in which poisoned-bran mash was compared with sodium arsenite dust, the former gave an average of 78 per cent mortality and the latter a 69 per cent mortality. The formula for the bait was 100 pounds of bran, 2 quarts of liquid sodium arsenite (4 pound material), 2 gallons of cane molasses, and 12 gallons of water. One pound of powdered sodium arsenite mixed thoroughly with 2 pounds of powdered talc made up the dust formula. The bran mash was scattered by hand at the rate of 10 pounds (dry weight) per acre. A rotary hand duster was used to apply the dust, which was applied at the rate of 10 pounds to the acre.

Comparative costs for the two methods were 15 to 20 cents per acre for the bait and 35 to 40 cents for the dust. It was found that the poisoned-bran mash was much easier to handle and less dangerous to the operator than the dust. The tests were made in a green barley field and considerable burning of the foliage resulted from the sodium arsenite dust.

METHODS OF SCATTERING BAIT. Several observations were made relative to the various means of scattering poisoned-bran mash. These methods were: (1) scattering by hand or end-gate seeder from the back end of a wagon, (2) scattering by hand from the back end of a motor truck, and (3) spreading the mash by airplane.

Scattering from the back end of a wagon, either by hand or end-gate seeder, a 30-foot swath was laid down at the rate of 3 miles per hour. This is about 11 acres per hour actual scattering time. Of the two methods, the end-gate seeder gave a finer and more even distribution of the bait but the particles dried out faster on the ground than did the larger particles from the hand scattering. With the seeder especial care had to be taken to feed the mash a little at a time into the hopper in order to prevent clogging. No difference was noted in the results of the two tests.

Spreading by hand from the back end of a truck a swath 30 feet wide was laid down at the rate of 5 miles per hour or about 18 acres per hour. This rate depends largely on the ability of the person scattering the bait.

In the experiment where an airplane was used to spread the mash as previously described, a 240-acre cornfield was covered in 2 hours and 40 minutes or at the rate of one and one-half acres per minute, or 90 acres per hour. This included loading, taking off, and landing. The landing field was just across the road from the cornfield. However, the small plane used could carry only 145 pounds of the wet mash at a time, necessitating 33 trips altogether. Distance from the landing field and nature of the field to be poisoned, together with the capacity of the plane, are

factors which determine the number of acres covered per hour. A very even distribution of the bran mash was obtained by this means and the results were satisfactory.

FEEDING HABITS. One of the most important considerations in the use of poisoned-bran mash is to scatter it just before or at the beginning of the period during which grasshoppers do their heaviest feeding. Failure to do this has often resulted in waste of materials and poor control. It was therefore considered highly desirable to study the feeding habits of both nymphs and adults. Grasshoppers were watched in the field throughout the entire day for a period of several weeks and records were made of light and wind condition and of the air and soil temperatures at which various activities took place. All temperatures are recorded in degrees Fahrenheit.

NYMPHAL FEEDING. Previous to the last few days of June, *differentialis* was present only in the nymphal stage and comparatively few *bivittatus* adults had appeared. Both species were largely confined to small grains, clovers, and alfalfa. As a general rule the young grasshoppers roosted all night high up on vegetation and remained there until the rays of the rising sun reached and started to warm the surface of the soil. They then descended to the ground and remained there until the soil became too hot. The next move was to seek the shaded side of clumps of vegetation and climb to a resting position several inches above the ground. Nymphs of both species were inactive at 60°F unless disturbed, and movements toward the ground did not take place at air temperatures below 65°. There was little feeding until air temperatures of 68° were reached and general feeding did not begin until the air temperature was 75°. This was true for either poisoned-bran mash or foliage. Feeding on bait continued until air temperatures approached 90° or exposed soil surface temperatures exceeded 112°, at which times the nymphs climbed vegetation to escape the extreme heat. Usually the nymphs were on the ground from 6 to 11 a.m. except on very warm days, when the period was considerably shortened. While some feeding on poisoned-bran mash took place throughout the range of 65° to 95°, maximum feeding was limited to a range of 75° to 85°. It should be noted, however, that feeding on poisoned-bran mash did not begin in the morning until the sun was high enough for its rays to strike and warm the ground surface, even though air temperatures before sunrise were within the range of maximum feeding.

Thermograph records kept in the field showed that minimum daily temperatures during June always occurred between 5 and 6 a. m. and ranged from 60° to 82°. It might have been expected that following a

night when air temperatures had remained within the maximum feeding range of 75° to 85°, heavy feeding would have started as soon as it became light, which was an hour or more before sunrise. Such was not the case. The grasshoppers, unless disturbed, invariably remained motionless high on the vegetation until the sun was high enough to shine on the ground. In other words, on clear days when minimum temperatures

TABLE 1. TIME OF DAY AND TEMPERATURES AT WHICH GRASSHOPPERS FED ON POISONED-BRAN MASH IN CORNFIELD AT HAMILL, S. D., JULY 22–26, 1931

| Beginning of Feeding | | | Maximum Feeding | | | End of Period | | |
|---|---|---|---|---|---|---|---|---|
| Time | Air Temp. °F. | Soil Temp. °F. | Time | Air Temp. °F. | Soil Temp. °F. | Time | Air Temp. °F. | Soil Temp. °F. |
| 6–7 a.m. | 68.6 | 69.8 | 9–10 am.. | 82.4 | 98.6 | 10–11 a.m. | 88.1 | 102.8 |
| 6–7 a.m. | 68.0 | 68.3 | 8–10 a.m. | 78.0 | 95.6 | 10–11 a.m. | 83.3 | 113.0 |
| 6–7 a.m. | 71.2 | 70.7 | 11–12 a.m. | 85.1 | 82.4 | 12–1 p.m. | 90.2 | 89.6 |
| 6–7 a.m. | 77.6 | 72.5 | 6–7 a.m. | 79.3 | 75.6 | 8–9 a.m. | 90.7 | 95.3 |
| 7–8 a.m. | 81.1 | 75.6 | 7–8 a.m. | 81.1 | 75.6 | 10–11 a.m. | 90.2 | 97.1 |

were above 65° the general movement toward the ground which marks the beginning of feeding on poisoned-bran mash took place shortly after sunrise each morning and was not limited by air temperature alone. On the other hand, the movement from the ground to the shade of vegetation, which marks the end of feeding on bait, was invariably at air temperatures between 90° and 95° except during migrations. During June these temperatures were sometimes reached by 8 a. m. and on such days the period of maximum feeding on poisoned-bran mash was greatly shortened and control was correspondingly more difficult. When nymphal bands were migrating the temperature limits of feeding were higher and nymphs were observed feeding ravenously on bait scattered across their line of march at an air temperature of 98°.

On cloudy mornings the nymphs remained inactive until the sun broke through the clouds. On one occasion noted the sky remained clouded until 9 a. m. and no feeding had occurred even though the air temperature was 80° F. As the clouds broke away there was a general movement toward the ground and heavy feeding started immediately. In control operations some of the heaviest kills were obtained when bait was scattered at the first sign of clearing skies.

ADULT FEEDING. Studies of the feeding habits of adults were made during the last two weeks of July. Temperature limits were the same for both species and did not differ materially from those reported for nymphs.

Table 1 shows the temperature limits of feeding on poisoned-bran mash set out in pans in a cornfield for a period of 5 successive days.

Counts of grasshoppers feeding were made every 10 minutes and baits were renewed at the end of each hour.

It will be noted in the table that feeding began at air temperatures varying from 68° to 81°F. and was more constant in regard to time than temperature. Like the nymphs, the adults remained on the corn until the slanting rays of the sun struck the ground. Then, if the air temperature was 68° or above, they descended from the corn and started to feed. On July 26 the sun did not break through the clouds until between 7 and 8 a. m. and as a result beginning of feeding and maximum feeding took place within the same hour at an air temperature of 81.1°. The period of maximum feeding occurred at air temperatures of 78° to 85° and varied in length according to the time of day at which the upper limits were reached. Feeding slackened at 86° and ceased at air temperatures above 90° or soil-surface temperatures above 112°.

MIGRATION OF NYMPHS. From June 10 to 29 migrations of nymphs were common. They were usually from one field to another close by and most often were headed for barley fields in which the vegetation was more succulent than in the field which the grasshoppers had left behind. Very few first and second instar nymphs were seen in migrating bands. Migrations were observed as early as 9.45 a. m. and as late as 6.00 p. m. The lowest air temperature recorded during migrations was 77° F. and the highest 99°. Wind seemed to have little effect on migrating bands but a cloud darkening the sun was sufficient to stop the migrations instantly.

In migrating, the nymphs moved in a "company-front" formation and if an obstruction was met they passed to either side and not over it. On one occasion when the young hoppers were migrating southwest across the corner of a cornfield toward green barley, individuals were watched closely to see just how they acted when on the move. Every individual was traveling in the same direction and was helping to strip the corn as he passed through the field. The corn was 3 to 4 inches high and as a young hopper reached a stalk of corn it would clamber up, take a few nibbles, and then hop down and pass on in the original direction just as if it knew where it was going. A close watch revealed that these hoppers never varied in their direction after their hurried feeding. Young succulent Russian thistles in their path received the same treatment and with the corn fell before the repeated onslaught of the migrating nymphs.

The almost complete destruction of small grains was not accomplished entirely by grasshoppers which hatched adjacent to the fields devastated. For a time some grain crops were unmolested, but sooner or later they were found by migrating bands of nymphs. These migra-

tions from field to field often resulted in one or more bands joining and forming a large army which then moved on with increased power of destruction. Migrating nymphs usually fed readily at any temperature when poisoned-bran mash was scattered across their line of march and excellent kills were obtained. Had there been enough bait available at this time many of the migrating armies could have been wiped out.

FLIGHTS OF ADULTS. Both *differentialis* and *bivittatus* have heretofore been considered weak fliers and non-migratory in the sense that they do not gather together in dense swarms and then suddenly leave en masse on extended flights to new territories. During the present outbreak both species displayed amazing individual powers of flight but a definite migration was never witnessed and no evidence has been found indicating that definite migrations to new territory took place.

A careful study of the flights of these two species in connection with temperatures, wind conditions, etc., indicated that they were due to a restlessness caused by high temperatures and showed no concerted action. In every case these movements began and ended at practically the same air temperature and were individual.

When air temperatures reached 86° to 90° F. adults would be seen rising suddenly here and there in short flights in all directions. As the temperature rose to 90° these movements increased until there were a large number milling around higher and higher. A swirl of wind would increase the numbers in the air. At temperatures above 90° the air as high as one could see would often be full of flying hoppers moving in all directions. There would also be a large number dropping back to the ground. A local aviator reported seeing a few hoppers flying as high as 1,400 feet but found that most of them were flying below the 600-foot level. At no time was there any definite direction to these flights except when the wind was blowing and then they were in the direction of the wind. During the time flights occurred the shady sides of telegraph and telephone poles, fence posts, buildings, trees, etc., were lined with resting grasshoppers. One observation showed the adults flying from a sun-baked barley field into the shade of buildings and trees adjoining. This movement started at 1.00 p. m., air temperature 92°. It would therefore appear that these flights were not true migratory movements but rather a restlessness caused by too high temperatures and that the grasshoppers were simply in search of cooler conditions.

Definite mass movements of adults did occur, however, in their search for green food. These movements were in the form of short low flights of 10 to 100 yards in length and were usually up wind toward green corn. Between flights the grasshoppers would walk or hop a short distance and

then take to the air again. Such movements began as early as 8.45 a. m. and at air temperatures as low as 78° F. and were in full swing when air temperatures reached 81°. *Differentialis* displayed stronger powers of flight and was more active on the ground than *bivittatus*.

DIFFERENCES IN RESPONSE TO TEMPERATURE. *Differentialis* and *bivittatus* occurred together in the present outbreak and their activities were confined within the same temperature limits. However, there was a difference in their seasonal history and a possible explanation is found in the results of rearing the two species in the laboratory at known temperatures. A large number of individuals of each species were reared to maturity at constant temperatures of 70°, 75°, 80°, 85°, 90°, 95°, and 100°F. At all of these temperatures the length of the nymphal stage of *bivittatus* was from 4 to 9 days shorter than that of *differentialis*. In other words *differentialis* requires more heat for its development. This is evidenced by the seasonal history and also in the distribution of the two species, the northern limit of *differentialis* being southern Minnesota and southern North Dakota, while *bivittatus* extends well into Canada.

It was also found that in the laboratory individuals of *bivittatus* varied considerably in their rate of development even when specimens were kept under identical conditions, whereas individuals of *differentialis* went through their development with a clocklike regularity in the length of nymphal instars. Similar differences were noted under field conditions and were especially striking in connection with the first appearance of adults. Adults of *bivittatus* appeared in small numbers early in June, increasing gradully in abundance throughout the month. No adults of *differentialis* were seen until the last few days in June, when four days of extremely high temperatures caused them to appear in countless millions almost overnight. As a result farmers who thought they were making good progress in protecting their corn from invasions of marching nymphs suddenly found their cornfields filled with winged adults which in some cases destroyed the entire crop within two or three days' time. This capacity for sudden, unexpected, and enormously increased distruction, due largely to its more uniform response to temperature, makes *Melanoplus differentialis* an even more dangerous grasshopper than *M. bivittatus*.

PROSPECTS FOR 1932. Parasites of nymphs and adults and egg predators were present in very limited numbers and there is no immediate promise of help by the insect enemies of grasshoppers. The unusually warm fall allowed females to lay their full quota of eggs, and these have gone into the winter in excellent condition. Unless weather unfavorable

to grasshoppers occurs after the eggs have hatched there is every reason to expect serious trouble over an even larger area in 1932.

PRESIDENT J. S. HOUSER: We will now hear a paper by Mr. A. G. Ruggles.

## OBSERVATIONS ON A GRASSHOPPER OUTBREAK IN MINNESOTA[1]

By A. G. RUGGLES, *St. Paul, Minn.*

ABSTRACT

A statistical survey of 123 farms in the heavily infested grasshopper area of Minnesota in 1931 with particular reference to the value of poisoned bran bait.

This survey was conducted (1) because little statistical information concerning the actual results from the use of poisoned bran bait for grasshoppers on a large scale is available and (2) to add to these statistical data already known. The value of this bait is usually not questioned. The results obtained last season proved its worth to many skeptical farmers and others. The survey, here reported, was not conducted by correspondence but by actual contact with each of 123 farmers after the 1931 harvest had been completed. Much other statistical information was obtained at the same time such as kinds of crops grown, methods of application, number of infested acres per farm, egg-laying areas, etc., to be used as a basis for determining the bait requirements per average farm and county. The information obtained has been of considerable value in preparing for the expected outbreak this coming spring. The fall egg survey in this area showed conclusively that considerably less ovipositing took place on farms and areas where bait had been applied during the summer than on unbaited areas.

In our Minnesota campaign of 1931, unfortunately, control measures were not started until very late in the season. Most of the applications were made after the hoppers had reached the fourth and fifth instars. Heavy migrations were taking place from one farm to another during the latter part of the season, particularly in some sections.

The 123 farms surveyed were all located within an area of 625 sections of land. The baited and unbaited farms and fields in many instances were adjoining one another and in all cases the farms, baited and unbaited, were so close together that the results should be valuable.

[1]Journal Series—Paper No. 1085 of the Minnesota Agric. Exp. Station.

The poisoned bait formula used was as follows:

100 lbs pure bran
5 lbs crude white arsenic
2 gallons of mollases (black strap)
10 gallons of water

BAITED ACREAGE

| No. farms baited | Total acres baited | Average % loss to crops | Average No. applications | Kind of crops |
|---|---|---|---|---|
| 69 | 3,777 | 28.85 | 2.32 | flax, wheat, barley, oats, alfalfa, sweet clover, potatoes, sugar beets, corn, beans, gardens |

UNBAITED ACREAGE

| No. farms unbaited | Total acreage in crops | Average % loss to crops | Total acres baited | Kind of crops |
|---|---|---|---|---|
| 54 | 11.425 | 76.26 | 0 | Same as above |

The following table summarizes crop losses according to the number of applications:

| No. applications | Crop loss in % | Crops |
|---|---|---|
| 1 | 31.46 | Same as above |
| 2 | 26.25 | |
| 3 | 20.31 | |
| 4 | 7.50 | |
| *5 | 32.50 | |
| 6 | | |
| *7 | 51.50 | |

*Farms where 5 and 7 applications had been made were located in an area where continuous heavy migrations occurred from surrounding fields.

For any one who has not seen an outbreak of grasshoppers it is very hard to visualize the damage done. When one is told that crops were all destroyed he does not quite believe it. Only when one goes through the country and works with the insects at a given place does a realization of the great destruction come to him. Here are a few of the statistics of the individual farms. On one farm of 500 acres of which 360 acres were under the plow, 50% of all the crops of wheat, oats and barley were destroyed by grasshoppers. On another 500 acre farm of which 350 acres were under the plow, 80% of the wheat, oats and barley crops were destroyed. On a 160 acre farm of which all was under cultivation 100% of the barley was destroyed, 60% of the corn, 80% of the oats, 30% of the wheat and 90% of the garden crops. On a 160 acre farm of which 150 acres were in plow, 50 acres were in barley and alfalfa crops. All the barley was taken and 80% of the alfalfa. On another 160 acre farm of which 80 acres were in plow, 100% of the potatoes were destroyed, 80% of the oats and barley and 75% of the garden crops. On

a 320 acre farm of which 185 acres were in plow, 40 acres in flax and potatoes, 90% of the flax was destroyed and 50% of the potatoes.

A few cases of interest where the poisoned bran mash bait was used—On a 480 acre farm of which 55 acres were in potatoes and flax, with one application the farmer saved all of his potatoes and 70% of his flax. On another 172 acre farm one application was given to a 10 acre flax field and 70% of it was saved. A field of barley on the same farm was destroyed completely by grasshoppers. On a 420 acre farm, 100 acres of flax were poisoned twice during the season and the farmer suffered only a 20% loss. On another farm of 480 acres of which 150 were in flax and barley, two applications of poisoned bran mash were given during the season and the farmer obtained 60% of his barley and 70% of his flax. On another farm of 150 acres of flax 5 applications were given at different intervals and the farmer sustained a 10% loss. On another 400 acre farm of which 110 acres were in flax the farmer made three applications and suffered practically no loss from grasshoppers.

About $27,000 were spent in the grasshopper control campaign in Minnesota in 1931. In computing results it can be conservatively stated that for every dollar spent for poisoned bran bait, $100 worth of crops were saved.

PRESIDENT J. S. HOUSER: The next paper will be read by Mr. G. C. Decker.

## THE ROLE OF THE AIRPLANE IN GRASSHOOPPER CONTROL[1]

By C. J. DRAKE and G. C. DECKER

ABSTRACT

The airplane was used to scatter 200,000 pounds of poison bran mash to control grasshoppers in western Iowa, the mash being applied at the rate of 20 pounds (10 pounds of dry bait) to the acre. Two planes broadcast 20,000 pounds of mash each morning between 5:30 and 9:20. A commercial bait, prepared by feed mixer and blender, was used entirely in the work. This bait consisted of 80 per cent bran, 15 per cent molasses and 5 per cent crude arsenic. The planes distributed the bait very evenly and without danger of poisoning farm animals.

The investigations reported in this paper were made during the months of July, August and September, 1931, with headquarters for the airplane work at Missouri Valley (Harrison County) and Onawa

[1]Journal Paper No. B21 of the Iowa Agricultural Experiment Station.

(Monona County), Iowa. Of the numerous species of grasshoppers found in Iowa, this summer's outbreak was due largely to the over-abundance of *Melanoplus differentialis* Uhler, *M. bivittatus* Say, *M. femur-rubrum* De Geer and *M. mexicanus* Saussure.

A survey of the situation showed the grasshoppers to be more than normally abundant in almost every county of the state. According to reports from the county agents, 71 of the 99 counties were scattering poisoned bran mash by the end of the first week of August. In general, however, the infestation was quite spotted and not serious in most counties, the heaviest damage being done along the Missouri River in Harrison and Monona Counties. In the western portion of these counties the banks of the large drainage ditches, sandbars, sloughs and other waste areas were populated with hordes of grasshoppers varying in size from nymphs nearly half grown to mature hoppers. These areas together with permanent pasture fields and other favorable breeding grounds had served as temporary feeding centers from which the hoppers were spreading and migrating to the more succulent plants and cultivated crops.

As a very large percentage of the land needing treatment consisted of uncultivated ground, such as ditch banks, sloughs and overflow areas, and as migration was already in progress and egg-laying about to begin, the task of destroying the grasshoppers in these vast areas was undertaken by the state. The airplane, which had been used so successfully in dusting cotton, forest trees, alfalfa and other crops for the control of insect pests, appealed to the writers as the most promising method of treating these extensive areas, together with miles of ditch banks. These waste areas were in many places inaccessible to motor and horse drawn vehicles and in the absence of planes would have to be treated at a great expense of labor, toting the bran some distance on the backs of horses and men. The funds for the purchase of commercial bait, making surveys and hire of planes were furnished by the State Department of Agriculture.

The experimental work with the airplane was started on the David Seabloom farm near Missouri Valley on August 7, 3000 pounds of mash being scattered from the plane the first day. For this work a three passenger Curtis Robin cabin monoplane, propelled by a Wright J-6-5, 165 H. P. motor was secured of the Midwest Air Corporation, Omaha, Nebraska. This plane was flown over corn, alfalfa, pasture and ditch banks at different heights to determine the rate at which the mash should be sifted from the sack in order to scatter approximately 20 pounds (equals

about 10 pounds of dry bait) of mash to the acre. After determining these factors several hundred pounds of mash were scattered by plane over a ditch bank along one side of an 80-acre pasture field where several horses and 147 head of valuable cattle were grazing continuously. On this or other occasions, farm animals suffered no apparent ill effects from the poison bait. After these preliminary experiments no attention was given to cattle, sheep, hogs, horses and other animals in pastures, sloughs or other areas. It should be noted that several thousand farm animals were feeding, with impunity, in these areas day and night during and after treatment with poison mash.

The Curtis Robin cabin plane, as described above, was used for the greater part of the work. During the last two days, however, a Waco bi-plane propelled with a Wright J-5, 225 H. P. motor was also employed and proved almost as satisfactory as the cabin plane. Both planes were comparatively new and had been flown for only a few months. The average air speed of the Curtis Robin monoplane as it was flown during the grasshopper work was approximately 105 miles per hour and the Waco bi-plane averaged 114 miles per hour. These two planes scattered 20,000 pounds of mash each morning between 5:30 and 9:20. On August 30, near Onawa, the two planes spread 10,000 pounds of mash in one hour and forty minutes, the areas being treated varying from one to three miles from the landing field. Conditions for flying were fairly good, except for a moderately strong breeze and a short landing field which required the planes after landing to turn and taxi back to the loading point and then turn again before loading and taking off for another trip. During the period between August 7 and 31, 200,000 pounds of mash were scattered by plane covering 8,700 acres of waste land, 115 acres of corn, 33 acres of alfalfa and 231 miles (both sides equal 462 miles) of ditch bank.

A ground crew of three men, including the truck driver, was used at the landing field so that loading might be accomplished in a minimum period of time. After the scattering by plane was completed in the morning, this crew moistened and prepared the bait needed for the following day. When working within a mile of the landing field, a plane made a round trip in four to five minutes, but, when the infested area was five miles or a little farther from the field, the trip required about nine or ten minutes.

Commercially prepared bait,[2] composed of 80 per cent bran, 15 per cent black strap cane molasses and 5 per cent of a commercial grade of finely powdered crude white arsenic ($As_2O_3$), was used in the airplane control work. Before being spread from the plane the bait was made into a mash by adding water at the rate of 9 to 10 gallons for each 100 pounds of dry bait. This bait was purchased for $22.50 per ton, f.o.b. Des Moines, in 100-pound burlap bags.

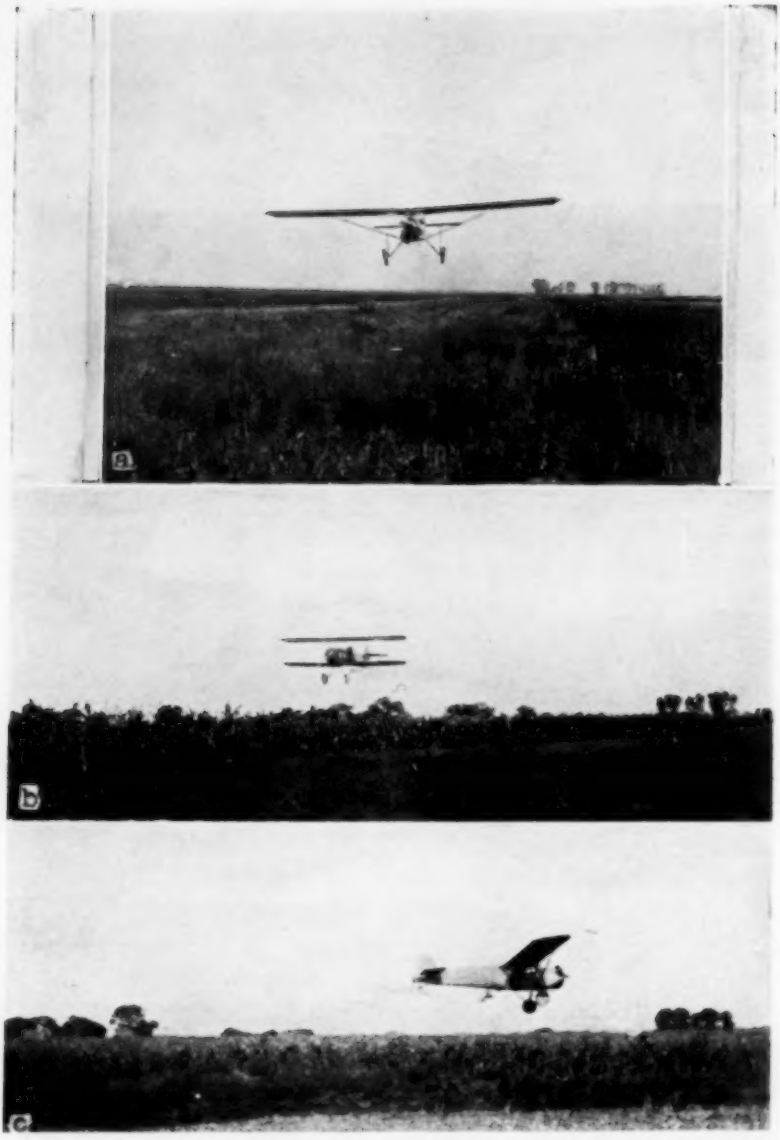
The commercial bait, as prepared by feed mills, has certain advantages over the home made baits, being cheaper, more uniform and ready to scatter as soon as the water is added. A modern feed mixer and blender, after being regulated and set, prepares the bait automatically. The blenders regulate the proportions of the different ingredients and keep them very constant, the bran and arsenic running together in a spout to the mixer where the molasses is added hot, by means of a special pump. After being thoroughly mixed the bait is run into sacks of 100 pounds each and handled the same as molasses impregnated bran for cattle feed. After the operation is started a good blender and feed mixer turns out the bait at the rate of about 20 or 25 tons per hour. Molasses, when added very hot, penetrates the bran better and also serves as a more satisfactory binder for the poison and bran.

As no mechanical devices were available for handling and scattering the mash during flight, it was necessary to have another man besides the pilot in the plane to feed and regulate the flow of mash from the sack. When slightly below the floor of the plane the mash was caught and apparently "exploded" by the strong air blast from the propeller so that the scattered bran fell largely as individual flakes upon the ground and vegetation. In fact the mash is spread more uniformly and evenly by the plane than it can be broadcast by hand. Three sacks of mash, each containing from 120 to 140 pounds, were carried each trip, one sack being placed on the floor of the cabin, one on the seat leaning against the closed side of the plane beside the man doing the

[2]Very similar commercial bait was used in South Dakota and Nebraska during the past summer by both federal and state officials. Dr. J. R. Parker, Mr. R. L. Shotwell and others successfully treated by plane a large corn field near Winner, South Dakota, with poison bran mash during July, 1931.

Nikolaevski (Za Rekonstr. sel'sk. Khoz., 11, 1930, pp. 38–40), and Tzuigankov, Orlov and Golovizin (Khlopkovoe Delo, IX, 1930, 1366–1370), have discussed the advantages and disadvantages of using airplanes for broadcasting poison bait (dry and moist) for the control of locusts and grasshoppers in central Asia.

Scattering poison bran mash by means of airplane. a. Monoplane scattering mash along the edge of a corn field at an altitude of 20 feet; b. Monoplane treating a corn field at an altitude of 40 feet. Ed. Seabold farm, Missouri Valley, Iowa; c. Corn and sweet clover totally destroyed by grasshoppers, near Sargent Bluffs, Monona County, Iowa.



a. Monoplane dusting poison bran mash along a small lateral ditch, Harrison County, Iowa; b, Waco bi-plane treating a corn field, Monona County, Iowa; c, Curtis Robin monoplane treating a small lateral ditch, Monona County, Iowa.

scattering and the other across his lap. When treating cultivated areas the plane flew back and forth across the field until all the sacks were emptied. Along ditch banks and other long stretches the flight continued straight ahead until a sack was emptied and, while the second or third sack was being transferred to the lap of the scatterer, the pilot made a short circle so that scattering of the next sack would begin where the preceding had left off.

TABLE 1. ACREAGE TREATED PER HOUR

| Area treated | Distance from landing field miles | Acres treated | Time in minutes | Approximate acres per hour |
|---|---|---|---|---|
| Alfalfa | 1 | 18 | 4.5 | 239 |
| Corn and alfalfa | .5 | 75 | 19 | 237 |
| Waste land | 1 | 300 | 90 | 200 |
| Waste land | 2 | 500 | 189 | 159 |
| Waste land | 2.5 | 250 | 105 | 140 |
| Waste land | 3 | 500 | 216 | 139 |
| Waste land | 4 | 250 | 120 | 125 |

The rate of mash delivery was varied with the altitude of flight because the higher the plane flew the wider the swath and the more mash it required to treat the strip covered by the trip. Wind is also an important factor, a strong side wind scattered the bait more widely and required an increased rate of feeding so as to cover a wider swath. In general, the plane flew from 20 to 50 feet above the ground, the altitude being varied to suit local conditions and thus avoid hazards of various types. Because of the human factor it was not possible to absolutely correlate the rate of mash flow with altitude, but as the same man did practically all of the scattering, it was very remarkable how proficient he became in keeping the vegetation and ground uniformly covered with the mash. In corn from 10 to 15 rows could be very evenly treated on one trip, the number of rows varying with the height of the plane above the ground.

In this connection it should be borne in mind that poison mash is an attractive bait not requiring such uniform coverage as the arsenicals used in dusting cotton, alfalfa or other plants. As grasshoppers are active and move about more or less in the field, it is not a serious error to lightly treat or even miss a small strip of ground. In broadcasting by hand it is not infrequently recommended that the infested area be treated in strips, sowing a swath about a rod wide and then leaving a similar strip untreated.

The number of acres which may be dusted with mash per hour with an airplane (Table 1) is somewhat variable and greatly influenced by

several factors and conditions. Among the more important should be mentioned the carrying capacity and air speed of the plane; size and condition of landing field; length of the infested area, thus avoiding too much turning and maneuvering for position; distance from the landing field; direction and velocity of the wind; and freeness of the area from shrubs, trees, telephone and high tension wires or other obstructions. Under the conditions prevailing during the past summer in western Iowa either of the planes used in the work was capable of treating from 130 to 200 acres per hour. The Curtis Robin cabin plane, which was used in most of the work, averaged 125 acres per hour for the summer. This includes time spent in experimental work, observational surveys, and the treatment of miles of drainage ditches and waste areas some distances from the landing fields. In large landing fields it was possible for the plane to land, load and take off without turning and taxiing to position as was necessary in the smaller fields. In many cases it was imposible to secure suitable landing fields adjacent to sloughs, sandbars and other waste areas. The nature of the large drainage ditches with their laterals as well as waste areas made it necessary that a considerable portion of the work be done at some distance from the landing field. Hence, the areas treated undoubtedly consumed much more time than would a similar acreage of cultivated land.

The plane, including a pilot and an assistant to scatter the mash, were secured by contract for twenty dollars ($20.00) per flying hour. This figure is slightly higher than the rate for commercial flying of these planes, but considering the hazardousness and greater risk of continued flight at such low elevations over waste areas, the rate seems fairly reasonable. The cost per acre of broadcasting grasshopper mash by plane varies with local conditions with the several other factors as discussed above. When operating within two miles of a good landing field, it should not exceed ten or twelve cents per acre. This cost, however, could be considerably reduced, perhaps 25 per cent or more, by the development of mechanical devices which would automatically feed and regulate the flow of mash from the plane and the use of larger planes in large areas. Mechanical devices would permit the plane to carry a larger load of grasshopper bran and enable the pilot to regulate the flow of the mash without the aid of an assistant. Furthermore, the mash would be distributed more evenly and with the uninterrupted mechanical flow of the bait the plane could treat ditch banks and other long stretches without turning.

Some of the advantages of the airplane are: Treatment is much faster than by other methods since a plane having a pay load capacity of 400 to 500 pounds will treat 800 acres or more in a morning; the mash is more evenly and uniformly distributed and is much safer from the standpoint of poisoning farm and wild animals because in the field all bait is handled at one point and spilled mash is more easily cleaned up; treatment by plane prevents hand scattering by temporary help (sometimes irresponsible), which may leave occasional piles or lumps on the ground; treatment is accomplished without any damage to crops from trampling by man, horses or vehicles; planes may be used to advantage to treat large acreages of corn and inaccessible waste areas; and preparing mash in large batches saves time in preparation, cleaning mixing floors and utensils.

In contrast with the above, some of the disadvantages are: Plane treatment is too costly in small areas; suitable landing fields are not always available, especially before harvest; planes with experienced pilots are not always securable at reasonable rates; and hire of plane requires a cash outlay and frequently does not permit the farmer to use available labor to best advantage.

PRESIDENT J. S. HOUSER: The last three papers are now open for discussion.

MR. J. G. BIGGER: I would like to ask whether or not the baits were spread by hand and the approximate cost.

MR. A. G. RUGGLES: We spread all our bait by hand with the exception of a few farms where an end-gate spreader was used. The cost was about 35 to 50 cents an acre. At the end of the season we were able to get crude arsenic at a very low price so the cost was considerably reduced.

MR. J. R. PARKER: We have been able to cover about ten acres per hour from the rear end of the wagon either by hand or with an end-gate spreader. The cost per acre would depend upon the labor charge. Our actual cost was about 13 cents an acre.

SECRETARY A. F. BURGESS: The reports indicate that the use of the poison bran mixture has been very effective. I would like to ask how much actual poison per acre is used in the mixture?

MR. J. R. PARKER: Half a pound.

SECRETARY A. F. BURGESS: It occurred to me that the distribution of poison in the way you mentioned gave very effective results with a very

small amount of poison compared with the amounts that are used in spraying other crops. A half pound of poison to the acre is much less than is used in spraying fruit trees or many other kinds of vegetation when leaf eating insects are to be controlled. Apparently the grasshopper is very easily killed if you make a general distribution of that amount of poison.

MR. J. R. PARKER: In the body of my paper I made a statement that so far as we could find out this was the most complete devastation of so large an area in the history of American entomology. I would like to know if there ever has been an area of approximately 30,000 square miles where the country in spots was completely devastated of all green vegetation.

PRESIDENT J. S. HOUSER: We will now hear a paper by Mr. J. H. Bigger.

## SHORT ROTATION FAILS TO PREVENT ATTACK OF *DIABROTICA LONGICORNIS* SAY[1]

By J. H. BIGGER, *Illinois Natural History Survey*

ABSTRACT

Experiments to determine the effect of rotations on certain corn root infesting insects have been under way in Illinois since 1928. The experiment field at Carthage, Ill., has had a 3-year rotation of Corn, corn, oats and sweet clover. This rotation has not controlled the Corn root worm, *Diabrotica longicornis* (Say). The rotation has been abandoned because of serious root worm damage.

During the season of 1928 a study was started in Illinois of the effect of various rotation practices on the abundance of certain corn root infesting insects in the field. In 1929 these studies were established on certain available fields of the Illinois Agricultural Experiment Station. This was accomplished through the coöperation of Dr. F. C. Bauer, in charge of soils experiment fields.

The results obtained on one of the rotations that has been used on the field located at Carthage in west central Illinois were striking. Because the evidence is contradictory to all prevoius reports, and because the rotation in question has now been abandoned, this matter is reported at the present time.

[1]Contribution from Project 3.7 of the Illinois Natural History Survey, Entomology Section, Urbana, Ill.

It is common to find in the literature of the Corn Root Worm such statements as the following: "A mere change of crops will bring relief," (1), or, "'. . .corn is rarely, if ever, liable to injury by this insect if planted on ground which had borne any other kind of crop the preceding year," (2). The evidence brought out by our studies shows that this is not always true, that more than one year of some other crop must be interposed between the successive corn crops to produce complete relief.

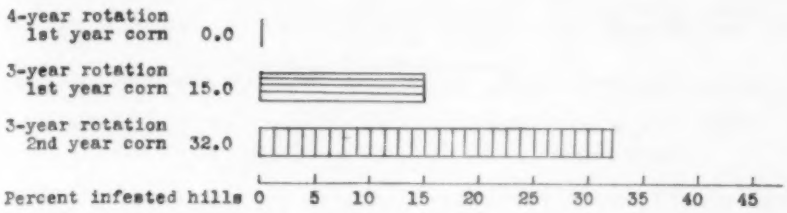

4-year rotation
1st year corn 0.0
3-year rotation
1st year corn 15.0
3-year rotation
2nd year corn 32.0
Percent infested hills 0 5 10 15 20 25 30 35 40 45

FIG. 6. Infestation by Corn Root Worm, *D. longicornis*, (Say), under different rotation practices. Carthage, Ill., Aug. 1–2, 1929.

ROTATIONS USED. Two rotations have been followed on the experiment field at Carthage. The principal or "Major" series has a 4-year rotation as follows: Corn, oats, red clover, wheat and sweet clover. The red clover is seeded in the oats one year and harvested the following year. After harvest the clover residue is plowed under and wheat is seeded on the field that fall. The following spring sweet clover is seeded in a portion of the wheat for a green manure crop, the remainder of the wheat being left without clover and supplied with a dressing of animal manure. Untreated check strips are left without either treatment. The field is plowed the following spring and corn is planted on the plots. The secondary or "Minor" series has had a 3-year rotation of Corn, corn, oats and sweet clover, the sweet clover being seeded in the oats in the spring and plowed under the next spring as green manure for the corn crop.

The major series has only one year of corn in the four years. There are three grass crops, but the order is broken so that a legume is interposed in two places in the four-year period. The minor series has had two years of corn in the three years of the rotation, and each of the three years has been a grass crop. The clover in the rotation has occupied the land during only a portion of one growing season. The latter rotation has failed to completely control the Corn Root Worm.

PROCEDURE. On this experiment field the land is plowed for corn during the middle of April and prepared in the usual manner. Selected and tested seed is planted by ordinary methods in use in the corn belt, the planting being done, if possible, the first part of May. Corn for use in the present experiments is planted on the land at the same time

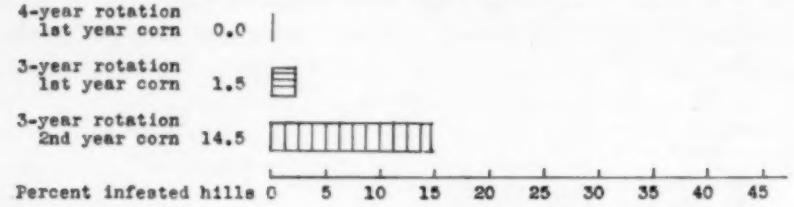



FIG. 7. Infestation by Corn Root Worm, *D. longicornis*, (Say), under different rotation practices. Carthage, Ill., July 21–25, 1930.

with a hand planter, being placed either in the margins of the plots or interplanted on the plots. Records are obtained by digging the corn and making a careful examination of the root system and surrounding soil. Three diggings are made, one early in June when normal plants are about 6 inches tall, another early in July at about the time of tasseling, and the last late in July or early in August when the ears are filling. The records of the Corn Root Worm are obtained at the last digging.

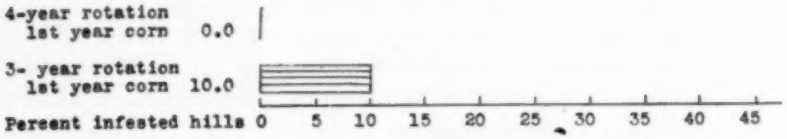



FIG. 8. Infestation by Corn Root Worm, *D. longicornis*, (Say), under different rotation practices. Carthage, Ill., July 27–28, 1931.

RESULTS. Some root worm infestation is found in the corn on the minor series the first year after oats and sweet clover. We have found this to be true for three successive years and have concluded that it is an established condition. Two of these years have been years of general scarcity of this insect. Corn on the major series has not shown infestation at any time.

Determinations of infestation for the purpose of this paper have been based at all times on the presence of newly emerged adults in the soil around the roots of the corn being dug, or just emerging from the soil at the time of digging. Adults flying freely in the field are not considered.

The numbers present in the plots are shown in the accompanying graphs. For the purpose of comparison there are also included the records of numbers found at the same time in the major series and in the second-year corn on the minor series. There is no second-year crop during 1931 due to changes in rotation which are being made in this series. These changes were necessitated by the severity of root worm damage to the corn.

LITERATURE CITED

1. WEBSTER, R. L. Common Corn Insects. Ia. C. 23, 6, 1915.
2. FORBES, S. A. Injuries to the Corn Plant and Its Products. Ill. Ent. R. 18, 142, 1892.

PRESIDENT J. S. HOUSER: We will now see the slides which accompany a paper by Messrs. C. J. Drake, B. V. Travis and E. V. Collins.

## A PRELIMINARY REPORT ON THE CONTROL OF WHITE GRUBS WITH A ROTARY PLOW[1]

By C. J. DRAKE, B. V. TRAVIS and E. V. COLLINS

ABSTRACT

Mechanical experiments for the control of white grubs by means of a Rotary Plow were conducted in virgin bluegrass pasture, timothy sod, and old corn stubble in southern Iowa, 96.7% of the grubs being killed during the plowing operation. Population, down (fall) and up (spring) migration, and transformation data were also secured for Brood A. The average grub population in a virgin 88-acre bluegrass pasture was 181,863 grubs to the acre, the most heavily infested spot yielding 223,245 grubs per acre. In the transformation and hibernation studies it was found that only 4% of the Phyllophaga spp. were within plow depth during the pupal and adult stages.

White grubs (*Phyllophaga* spp.) are among the most serious insect pests in Iowa. The present outbreak is a part of a general infestation extending from Connecticut, New Jersey and New York westward into Minnesota, Iowa and Missouri. The grubs first appeared in unusual numbers in the northeast corner of the State in 1909 and, since then, they have been spreading to the south and west with a distinct tendency to concentrate in the more hilly, broken and wooded areas. On account of the topography and soil conditions, a considerabe acreage of land in these areas is in permanent bluegrass pasture. Timothy is also grown quite extensively. Thus farm practices coupled with the natural con-

[1]Journal Paper No. B13 of the Iowa Agricultural Experiment Station.

ditions have been very favorable for both the larval and adult stages of the June beetles.

Practically all of the counties in Iowa have reported commercial damage from white grubs, Brood A being by far the most injurious. This brood caused very serious losses in a number of eastern counties in 1930. From the southeastern part of the State, the outbreak has spread west into Ringgold County.

The observation on the migratory movements preparatory to and following the hibernation of larvae, hiberation of larvae and adults, population studies and experimental work with the rotary plow were made in the vicinity of Leon, Lamoni and Garden Grove, Decatur County,[2] Iowa, in 1930 and 1931. In this county the heaviest losses from Brood A occurred in bluegrass, timothy and corn. Many other crops were also seriously injured or even totally destroyed.

The experiments with the Rotary Plow were started October 21, 1930, in a permanent blue grass pasture near Leon. At this date, migration for the winter was in progress, and only 40 per cent of the grubs were above the plow line. Of these, 95 per cent were killed during the plowing operation and the rest died from injuries within three days.

On account of the lateness of complete upward migration in the spring, the plowing experiments were delayed until almost the middle of May. The Rotary Plow was used in four different fields, a total of approximately 16 acres of ground being broken. The controls, one on each side of the experimental tract, were plowed with an ordinary moldboard plow. The four experimental tracts were located as follows: one in an old timothy field, two in permanent blue grass pastures, and one in an old corn stubble field. The plowing experiments were started in a permanent bluegrass pasture May 13, 1931, at which time only 53 per cent of the grubs were in the upper five inches of the soil. The second tract, located in a corn stubble field which had been almost totally destroyed by grubs during the previous summer, was plowed May 19–20, and 67.5 per cent of the grubs were within plow depth. The third tract, in a timothy field, was plowed May 21–23 and 94.8 per cent of the grubs

[2]According to Dr. P. E. Brown of the Soils Department, the soil in Ringgold County is known as Shelby loam. This soil is a dark brown loose loam, usually averaging 6–10 inches in depth, grading somewhat abruptly into subsoil consisting of yellow, heavy tenacious gritty clay showing some mottlings. Throughout the soil and subsoil some fine and coarse gravel and stones occur. In topography the soil varies from undulating or gently rolling to hilly and broken. The elevation at Leon is 1020 feet.

White grub damage, Brood A, Decatur County, Iowa: *a*, Bluegrass sod rolled back showing white grubs; *b*, Corn field almost totally destroyed by grubs, 1930; *c*, Illustrating (1) Results of Rotary Plow and (2) Moldboard Plow control experiments in 1931 (3rd year larvae).

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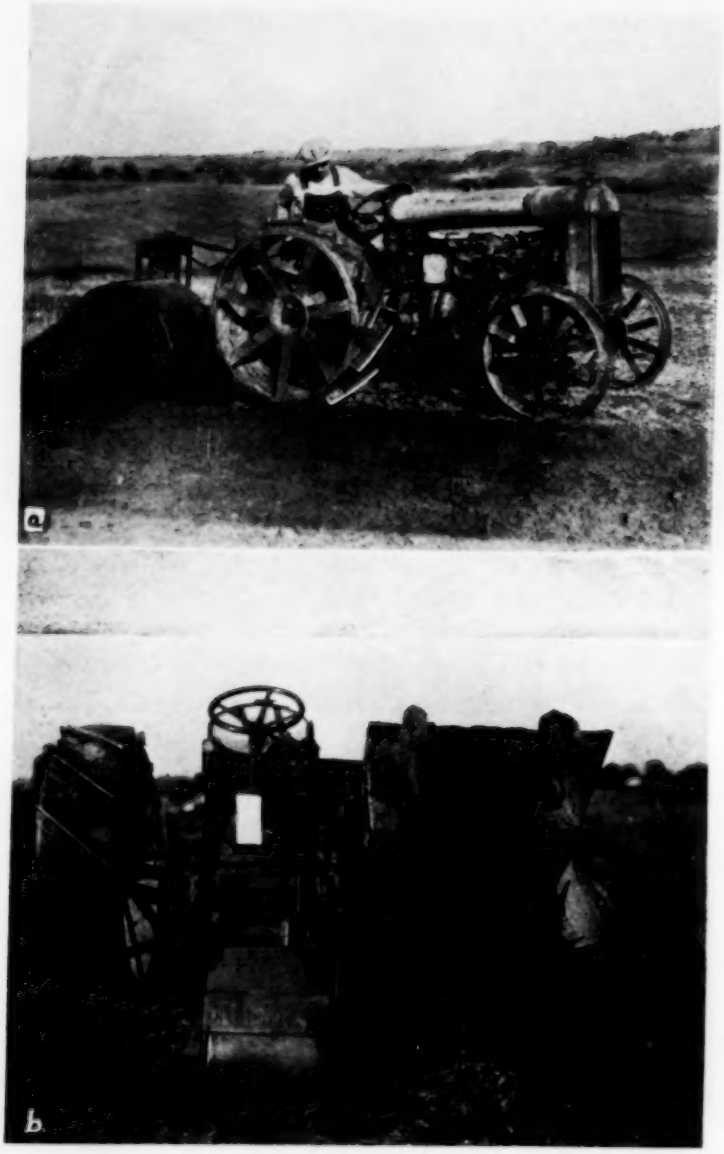


*a*, Rotary Plow in operation, virgin bluegrass pasture, Leon, Iowa, 1930; *b*, Back view of plow with shield lifted to show cutting blades.

were above the plow line. The fourth tract, situated on the north slope of a permanent bluegrass pasture, was plowed May 27, and only 68.1 per cent of the grubs were within range of the plow.

As soon as an experimental tract was plowed, counts were made to determine the percentage of grubs which had been destroyed. Some difficulty was experienced in determining the percentage killed because many of the grubs were so finely ground during the plowing operation that it was difficult to distinguish them. The control counts, made within twenty-four hours after plowing, showed that 96.7 per cent of the grubs had been destroyed by the Rotary Plow. Of the small percentage not killed during the plowing operation, most of them died within six days.

The Rotary Plow,[3] as used in these experiments, operates similar to a milling cutter. The cutting wheel is 32 inches in diameter and 14 inches wide and carries 16 steel blades. Power was taken from the belt pulley shaft of a Fordson Tractor to a jack shaft and then to the cutting wheel. A new Fordson (Model 1931) was used to operate the plow. The cutting wheel was driven at a speed of 150 revolutions per minute, the velocity of the blades being 1,250 feet per minute.

The capacity of the machine in old bluegrass sod in low gear is 2 acres per ten hour day with an estimated cost of operation of $6.75 per acre. Its capacity in intermediate gear is about 3.6 acres per ten hour day with an estimated operation cost of $3.50 per acre. This cost, however, may be considerably reduced by using a much wider and larger cutting wheel to reduce the acceleration losses. Such a plow would require a larger tractor to operate, but its efficiency would be greatly increased. Cutting the ground in thin slices and then throwing it violently against the shield destroyed over 96 per cent of the white grubs. This leaves the soil very level, finely pulverized and in such a condition that no further work is needed before planting. In addition to the white grubs, the plow destroyed cutworms, sod webworms, armyworms and numerous other insects as well as field mice and garden moles. In the areas where the plow was operated the wireworm population was not sufficient to secure definite mortality data. However, practically all of the wireworms observed after the plowing operation had been destroyed. The shape and thickness of the slices of soil are illustrated in Fig. 9 for both gears.

Of the soil-inhabiting and root-feeding white grubs, 31 different

[3]The Rotary Plow can not be operated satisfactorily in very stony soil.

species have been found in Iowa. Based on the literature and collection made by the writers, over 20,000 larvae and imagoes have been studied to determine the relative importance of the species involved. It is worthy of note in this connection that the same species dominate in Broods A, B and C. These fall in the first two groups as listed below.

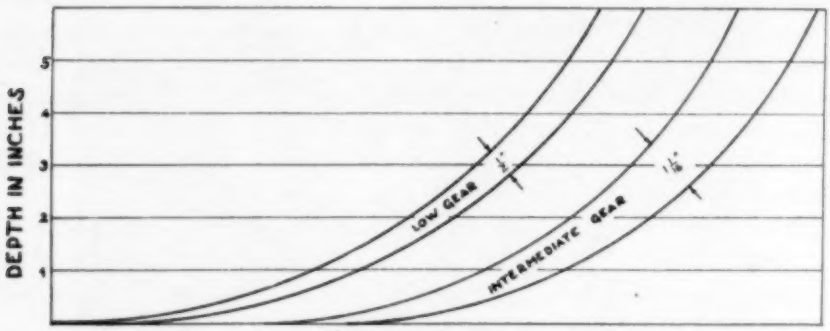



FIG. 9.—Cross section of slices made by blades of Rotary Plow.

(1) Extremely abundant—*Phyllophaga fusca* Froelich, *P. futilis* Lec., *P. hirticula* Knoch., *P. rugosa* Melsh., *P. implicita* Horn.

(2) Abundant—*P. crassissima* Blanch., *P. fraterna* Harris, *P. micans* Knoch. *P. inversa* Horn, *P. tristis* Fab.

(3) Fairly common or rare—*P. ilicis* Knoch., *P. crenulata* Froel., *P. vehemens* Horn, *P. drakei* Kby., *P. anxia* Lec., *P. fervida* Fab., *P. balia* Say, *P. biparta* Horn, *P. hornii* Sm., *P. quercus* Knoch., *P. villifrons* Lec., *P. nitida* Lec., *P. corrosa* Lec., *P. fosteri* Burm., *P. spreta* Horn, *P. marginalis* Lec., *P. prunina* Lec., *P. longitarsis* Say, *P. ephilida* Say, *P. lanceolata* Say, *P. barda* Horn.

In the population, hibernating and control studies, plats two feet square (2′x2′ or 4 sq. ft. and as deep as necessary) were used as units. The soil was cut vertically in one inch slices so that the depth of the grub from the surface of the ground could be determined accurately. The plats were located at random in bluegrass and timothy sod in areas showing various degrees of grub injury. In the corn fields a square plat representing one hill of corn (approximately 3′4″x3′4″ with the corn plants in the center) was used as a unit. The grub counts were made at fairly regular intervals in the fall and spring, only a few records being taken during the winter. Although the following data is based entirely on Brood A, some valuable notes were also secured concerning Broods B and C.

In a permanent bluegrass pasture tract near Leon, comprising 80 acres of virgin ground and 8 acres not cultivated for 40 years or longer, 67 plats yielded 1,122 grubs. The number of grubs in a plat varied from 0 to 52, the average being 16.7 grubs. At this rate the 88-acre tract would give an average population of 181,863 grubs to the acre. In the most heavily infested areas the population ran as high as 223,245 grubs to the acre. In another virgin bluegrass pasture field (100 acres) near Garden Grove, one-tenth of an acre was measured off, the grubs collected by hand and then counted. The actual population of this large tract was 3,372 grubs. The latter count was made on May 22 and 23, 1931. At the time these records were taken it was impossible to find a living blade of grass or weed in this plat on account of the abundance of the grubs. In these areas and others, many of the grubs apparently perished of starvation before transformation because of the food shortage, due largely to the over-abundance of grubs and drought conditions.

The grubs were not as abundant in timothy as in bluegrass sod. A small timothy tract of 4 acres near Garden Grove which had been very seriously injured by the grubs during the previous summer, was selected for the studies. The 13 plats gave a total population of 116 or 8.9 larvae per unit. These records were taken during May and April, 1931.

The data in corn were secured near Garden Grove and Lamoni. These fields were either timothy or bluegrass sod in 1929, the oviposition year for Brood A. During the fall (1930) and spring (1931) 364 grubs were taken from 37 plats, giving an average of 9.8 grubs to the hill. The maximum number found feeding on the roots of a single hill was 35 third year larvae. The grub population and nature of the "grub-spots" presented definite evidence of some lateral migration. In a number of these spots the population was so great that the grubs had either to migrate or starve after the roots of the young plants had been consumed. As the season advanced, there was a concentric widening of these spots so that by fall the injury graded from small dead plants in the center to slightly injured or normal hills at the margin. The plat records gave an average population in the central area of 4.3, whereas the hills near the periphery averaged 14.1 grubs. Field records also indicate that some of this difference is probably due to a higher mortality in the center of the grub spots because of unfavorable food conditions during the latter part of the summer.

The second year larvae started down migration between October 12 and 17, 1930, the first hard freeze occurring on the night of October

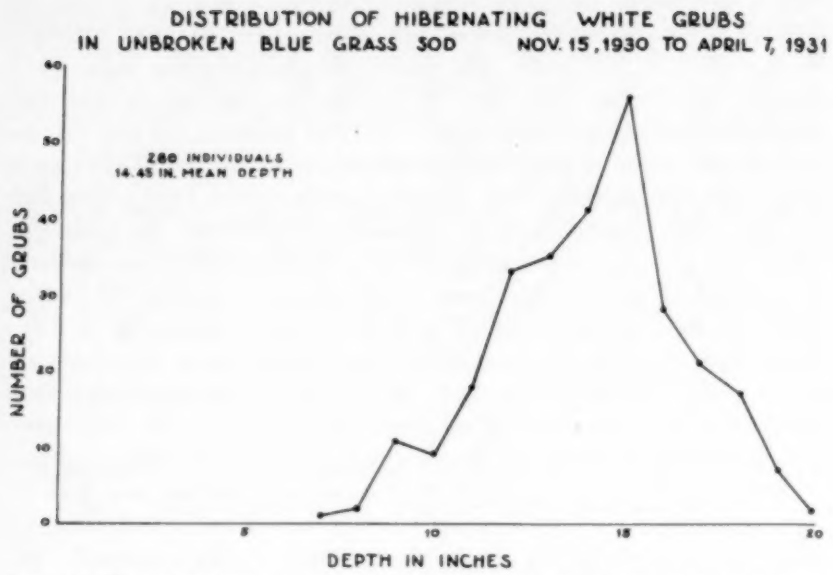

DISTRIBUTION OF HIBERNATING WHITE GRUBS
IN UNBROKEN BLUE GRASS SOD NOV. 15, 1930 TO APRIL 7, 1931
280 INDIVIDUALS
14.45 IN. MEAN DEPTH
NUMBER OF GRUBS
DEPTH IN INCHES

FIG. 10.—Records taken at Leon, Iowa, between Nov. 15, 1930 and April 7, 1931.

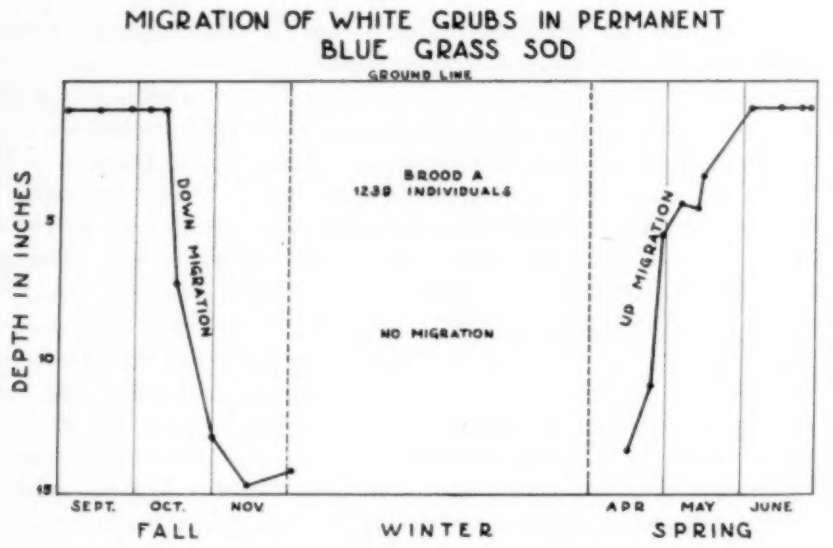



FIG. 11.—Down (second year larvae, Fall 1930), and Up (third year larvae, Spring 1930) Migration of White Grubs, Leon, Iowa.

15. By November 14 migration was complete and all of the grubs had secreted themselves in earthen cells for hibernation. In bluegrass sod the maximum depth of migration was 22 inches, the minimum 7 inches and the mean 14.45 inches; in timothy the maximum was 24 inches, the minimum 13 inches and the mean 15.55 inches. The heavy clay subsoil, coupled with a severe drought, undoubtedly had a marked effect on

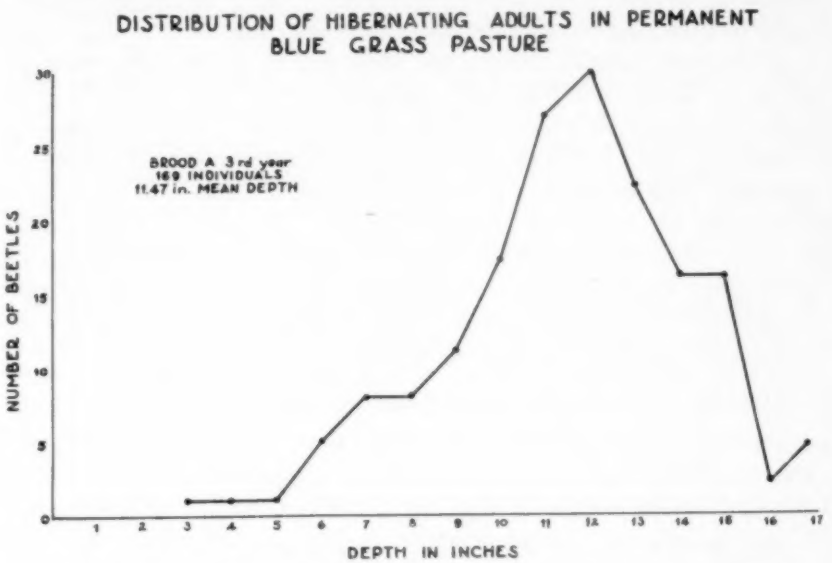



FIG. 12.—Distribution of pupal cells in virgin bluegrass pasture, Leon, Iowa, 1931–32.

down migration as the grubs rarely penetrated the subsoil to a depth of two or three inches. The results of the hibernation studies in bluegrass sod are given in Fig. 10.

The up migration started between April 7 and 16 and was complete by May 19, 1931, except in corn fields and the 8-acre portion of the 88-acre tract. In the latter the subsoil was so dry and hard that up to May 27 only 68 per cent of the grubs had migrated to the top layer of the ground. The fall and spring migrations are shown in Fig. 11.

During the third year all of the grubs stopped feeding between July 1 and 24, 1931, then migrated deeper into the soil before forming pupal cells. Pupation began July 24 and ended August 19. The adults issued between August 20 and September 24. After transformation the adults remained in the earthen cell prepared by the larvae for pupation and there was no evidence of any vertical or horizontal migration during the

latter part of the summer or fall. These cells serve as hibernating shelters for the winter. The maximum depth of pupation was 17 inches, the minmum 3 inches and the mean 11.47 inches. As the adults spend the period from pupation to emergence in these cells, and as 96 per cent of the pupae or adults are below the plow line, it is quite evident that late summer, fall or winter plowing would be of little value as a control measure. The locations of the earthen cells within which transformation and overwintering occur in the soil are given in Fig. 12.

While excavating for the larvae, pupae and adults of June beetles, 65 pupae of Tiphia and Elis were collected in 1930 and 68 in 1931. In 1930 the maximum depth of these pupae was 16 inches, the minimum 1 inch and mean 7.26 inches; in 1931 the maximum was 17 inches, the minimum 3 inches and the mean 12.19 inches. Of these, 33 were within five inches of the surface in 1930 and only 1 in 1931. Drought conditions of 1930 seem to account for these differences. These two species parasitized about 3 per cent of the grubs in the 88-acre bluegrass tract, slightly over 43 per cent in the 100-acre bluegrass pasture, 6 per cent in the corn and 7 per cent in the timothy sod.

Mr. G. C. Decker explained the slides on this paper.

PRESIDENT J. S. HOUSER: The rotary plow would not work on stony soil, would it?

MR. G. C. DECKER: I believe not.

MR. W. P. FLINT: I would like to ask the cost of running it per acre?

MR. G. C. DECKER: The experiment was conducted in coöperation with the Agricultural Engineers and the costs were $3.50 per acre in intermediate gear and $6.75 per acre in low gear.

PRESIDENT J. S. HOUSER: Is this plow on the market?

MR. G. C. DECKER: I believe it was a plow procured from the Agricultural Engineers at the corn borer laboratory in Ohio.

PRESIDENT J. S. HOUSER: The next paper is by W. G. Baerg and C. E. Palm.

# REARING THE ROUGH-HEADED CORN STALK-BEETLE[1, 2]

By W. J. BAERG and C. E. PALM, *University of Arkansas*

ABSTRACT

The rough-headed corn stalk-beetle (*Euetheola rugiceps*) is a local pest in Arkansas. Under certain conditions the stand of corn is destroyed in numerous localities scattered over a large part of the state. Life history studies reported in this paper deal with preparation of food materials, and give the duration of the various developmental stages.

The rough-headed corn stalk-beetle is prominently mentioned in early American economic entomology, and in the region where it is relatively abundant it probably made its appearance as a corn and sugar-cane pest as soon as these crops became available. Serious losses caused by this beetle were reported in Louisiana[3] prior to the Civil War, about 1856–57. From Arkansas[4] the pest was first reported from St. Francis County in 1888, as having done considerable damage. The beetles were reported as literally swarming about the lighted lamps. Since then this species has been reported from 41 (out of 75) counties. Judging from the distribution of these reports, the species occurs in every county in the state, but in appreciably injurious numbers largely in the southern half of the state and in the two eastern tiers of counties. However, although somewhat widely distributed, the serious damages have been local, involving a few fields here and there, not any widespread areas.

Notwithstanding this rating as a pest, there has not appeared any complete life history study of the rough-headed corn stalk-beetle. A very good account of field observations has been published by Phillips and Fox.[5] These investigators undertook to rear the beetles, and although they secured but four adults, and these indoors subjected to artificial heat, they have contributed much information on proper food materials and methods of handling.

The beetles used in these experiments were collected about lights at the Rice Branch Experiment Station near Stuttgart. The rearing work was done at Fayetteville during the seasons of 1930 and 1931.

[1]Research Paper No. 261, Journal Series, University of Arkansas.

[2]*Euetheola rugiceps*, Family Scarabaeidae, Order Coleoptera.

[3]Titus, E. S. G. The sugar-cane beetle. U. S. B. E. Bul. 54, p. 7–18. 1905.

[4]Webster, F. M. Notes upon some insects affecting corn. Insect Life, vol. 3, p. 159. 1890.

[5]Phillips, W. J. and Fox, Henry. The rough-headed corn stalk-beetle. U. S. D. A. Bul. 1267. 1924.

OVIPOSITION. To secure eggs, beetles of both sexes were kept in jelly tumblers nearly filled with soil in which a few kernels of corn were buried. The soil, which was of a light sandy type, was sifted and kept

TABLE 1. *E. rugiceps*. (1930). INCREASE IN SIZE OF EGGS. (SIX EGGS WERE MEASURED EVERY DAY, FROM OVIPOSITION TILL HATCHING, FIVE FOR TEN DAYS, ONE FOR NINE DAYS)

| | First measure | Last measure | Increase | Average daily increase |
|---|---|---|---|---|
| (1) Length | 1.594 mm. | 2.188 mm. | 1.594 mm. | .159 mm. |
| Width | 1.313 mm. | 2.000 mm. | .687 mm. | .069 mm. |
| (2) Length | 1.625 mm. | 2.344 mm. | .719 mm. | .072 mm. |
| Width | 1.313 mm. | 1.969 mm. | .656 mm. | .066 mm. |
| (3) Length | 1.594 mm. | 2.188 mm. | .594 mm. | .059 mm. |
| Width | 1.313 mm. | 1.938 mm. | .625 mm. | .063 mm. |
| (4) Length | 1.625 mm. | 2.375 mm. | .750 mm. | .075 mm. |
| Width | 1.281 mm. | 1.938 mm. | .657 mm. | .066 mm. |
| (5) Length | 1.625 mm. | 2.438 mm. | .813 mm. | .909 mm. (9th day) |
| Width | 1.281 mm. | 2.031 mm. | .750 mm. | .083 mm. |
| (6) Length | 1.563 mm. | 2.250 mm. | .687 mm. | .069 mm. |
| Width | 1.313 mm. | 1.938 mm. | .625 mm. | .063 mm. |

Average increase in length ..... .693 mm.
General average daily increase in length ..... .0707 mm.

Average increase in width ..... .667 mm.
General average daily increase in width ..... .0683 mm.

moderately moist. This is essentially the method employed by Phillips and Fox. During the past season no effort was made to determine the number of eggs laid by one female. In the season of 1930, observations showed that one female may deposit no less than 101 eggs in a period extending from July 8 to August 26. There is no evidence that the egg-laying capacity is not greater than this. During the past season, 1931, a total of 410 eggs were obtained from June 13 to August 28. Since the beetles were kept under conditions approximately normal, there are reasons to believe that in the field the egg laying period covers about three months.

Other investigators have observed that the eggs enlarge very considerably during incubation. Six eggs measured daily for ten days showed an average total increase in length and width of 1.5 times. Since the increase in width is proportionately greater than the increase in length, eggs about to hatch approach a globular shape. (See Table 1.)

To determine the increase in weight, six eggs were weighed on the date of oviposition and again eight days later (shortly before hatching).

At the first weighing the eggs ranged from .0014 to .0017 grams, at the last from .0040 to .0050, giving an average increase of .0031 grams. (See Table 2.)

TABLE 2. INCREASE IN WEIGHT OF EGGS. (SIX EGGS WEIGHED ON DATE OF OVIPOSITION AND AGAIN EIGHT DAYS LATER, JULY 25 TO AUGUST 2)

| First weight | Last weight | Increase |
|---|---|---|
| .0015 grams | .0046 grams | .0031 grams |
| .0015 grams | .0046 grams | .0031 grams |
| .0015 grams | .0043 grams | .0028 grams |
| .0017 grams | .0050 grams | .0033 grams |
| .0014 grams | .0048 grams | .0034 grams |
| .0014 grams | .0040 grams | .0026 grams |
| Average of total..... | | .00305 grams |

Increase in weight is about three times.

INCUBATION. The eggs were removed daily from the soil in which the beetles were kept, and placed in one-ounce tin salve boxes, partly filled with finely sifted soil moderately moist. The soil was pressed down somewhat to provide shallow depressions and a smooth surface so that the eggs are easily seen.

Of 410 eggs, 255 hatched in from 10 to 15 days, with the exception of a few hatching late in September, which required 16 to 17 days. The average time required is 12 days.

In 1930 (June 30 to July 27) incubation records were obtained on 105 eggs. These hatched in from 9 to 11 days, with an average of 9.85 days. This lower average is apparently due to higher temperatures.

The young larvae soon after hatching burrow into the soil and commence to feed. To provide food materials on which the larvae will thrive has been for various investigators a somewhat serious problem. Phillips and Fox[6] after numerous trials found a vegetable mold obtained from grasses of the genus Paspalum and Japan clover most satisfactory. As the larvae increased in size they added a kernel or two of corn previously soaked in water.

Vegetable mold has proved unsatisfactory in our experiments. The larvae feed on it, but their development seems abnormally slow, and many die before they reach the pupal stage. After various materials had been tried we adopted a mixture composed of equal parts of a fairly light sandy soil rich in humus, and a heavy loam found in low spots where Juncus grasses grow. These soils were carefully sifted, mixed thoroughly, and kept moderately moist in flower pots. The moisture content which proved most satisfactory for larval development averaged 18.74 per cent.

[6] *Loc. cit.*

The young larvae were kept in one-ounce salve boxes nearly filled with the soil mixture. After transforming to the second instar, the larvae were supplied with several kernels of corn sprouted in rag-doll fashion. Some of the larvae apparently fed largely on the fine root hairs, most of them, however, on the contents of the kernel (endosperm). In the third and last instar the larvae were transferred to two-ounce salve boxes and fed as before. The soil was renewed about every other day, to maintain sanitary conditions as well as to furnish a part of the food.

The greater number of the larvae were reared in a pit, where they occupied a position about three feet beneath the surface of the ground. Here the daily fluctuations of temperature were only about two degrees, and relative humidity was about 90 per cent. These conditions we believe approach closely those under which the species lives in the field.

When the proper food materials were provided and the temperature and humidity were suitable, larvae were reared without any serious fatalities. A few died from an attack of a fungus, and a few were attacked by mites. During the latter part of the season some of the pupae were afflicted with a malady, possibly a bacterial infection, which gradually changed them from the natural pale orange to dark brown and finally dull black. This malady became increasingly serious as the cool weather of fall set in.

Duration of Instars. A few of the larvae were reared in incubators kept at constant temperatures and humidity, and some on an open shelf in the insectary subject to considerable fluctuation in temperature. The 216 larvae completing the first instar required from 8 to 33 days, with an average of 19.13 days. In the pit the shortest time required was 14 days. The larvae completing in less time were in incubators kept at a temperature of 31–35 degrees C., and a humidity of 80 per cent.

The 163 larvae completing the second instar required from 8 to 38 days, with an average of 19.8 days. The shortest time required for larvae reared in the pit was 14 days. Those completing in less time were reared in an incubator.

The third instar, for 85 larvae, required from 17 to 40 days, with an average of 28.9 days. This includes the prepupal period. The prepupa has been described by Phillips and Fox.[7] The period is not very sharply limited. It begins when the larva ceases to feed and is later characterized by change in appearance. If the larva fed exclusively on corn, cessation of feeding would be easily observed, but slight feeding on the soil and humus mixture is not easily seen.

[7] *Loc. cit.*

For 75 prepupae the period ranged from 3 to 11 days, with an average of 6.8 days.

TABLE 3. SUMMARY OF REARING DATA

| Lot No. | Date of hatching | Date of 1st molt | Date of 2nd molt | Date of pupation | Date of appearance of adult | Total No. of days | |
|---|---|---|---|---|---|---|---|
| 9.41 | July 12 | Aug. 2 | Aug. 16 | Sept. 7 | Sept. 19 | 69 | |
| 9.21 | July 12 | July 29 | Aug. 15 | Sept. 8 | Sept. 20 | 70 | |
| 9.21 | July 5 | July 27 | Aug. 11 | Sept. 8 | Sept. 23 | 80 | |
| 32.22 | Aug. 4 | Aug. 14 | Aug. 28 | Sept. 14 | Sept. 24 | 51 | Inc.[5] |
| 32.31 | Aug. 4 | Aug. 15 | Aug. 25 | Sept. 13 | Sept. 24 | 51 | Inc. 1 |
| 3.21 | July 6 | July 27 | Aug. 11 | Sept. 10 | Sept. 25 | 81 | |
| 3.11 | July 6 | July 25 | Aug. 15 | Sept. 11 | Sept. 25 | 81 | |
| 32.21 | Aug. 4 | Aug. 14 | Aug. 25 | Sept. 19 | Sept. 29 | 56 | Inc. 1 |
| 7.21 | July 10 | July 29 | Aug. 17 | Sept. 15 | Oct. 1 | 83 | |
| 11.41 | July 14 | Aug. 2 | Aug. 19 | Sept. 15 | Oct. 1 | 79 | |
| 8.11 | July 11 | July 27 | Aug. 16 | Sept. 15 | Oct. 1 | 82 | |
| 9.12 | July 12 | July 27 | Aug. 17 | Sept. 16 | Oct. 2 | 82 | |
| 2.22 | July 5 | July 27 | Aug. 17 | Sept. 16 | Oct. 3 | 90 | |
| 10.31 | July 13 | July 30 | Aug. 20 | Sept. 16 | Oct. 3 | 82 | |
| 12.11 | July 15 | Aug. 4 | Aug. 21 | Sept. 16 | Oct. 3 | 80 | |
| 10.21 | July 13 | July 29 | Aug. 20 | Sept. 17 | Oct. 5 | 84 | |
| 13.21 | July 16 | Aug. 4 | Aug. 22 | Sept. 17 | Oct. 5 | 81 | |
| 8.31 | July 11 | July 30 | Aug. 20 | Sept. 17 | Oct. 5 | 86 | |
| 40.12 | Aug. 12 | Aug. 21 | Sept. 2 | Sept. 25 | Oct. 5 | 54 | Inc. 5 |
| 1.13 | July 4 | July 27 | Aug. 18 | ——— | Oct. 6 | 94 | |
| 1.12 | July 4 | July 27 | Aug. 17 | ——— | Oct. 6 | 94 | |
| 41.11 | Aug. 13 | Aug. 23 | Aug. 31 | Sept. 26 | Oct. 6 | 54 | Inc. 5 |
| 20.31 | July 23 | Aug. 13 | Aug. 28 | Sept. 21 | Oct. 7 | 76 | Insectary |
| 15.11 | July 18 | Aug. 3 | Aug. 24 | Sept. 20 | Oct. 8 | 81 | |
| 44.41 | Aug. 16 | Aug. 29 | Sept. 6 | Sept. 28 | Oct. 8 | 53 | Inc. 1 |
| 19.11 | July 22 | Aug. 7 | Aug. 24 | Sept. 21 | Oct. 9 | 79 | |
| 9.51 | July 12 | Aug. 3 | Aug. 24 | Sept. 21 | Oct. 9 | 89 | |
| 44.11 | Aug. 16 | Aug. 26 | Sept. 5 | ——— | Oct. 9 | 54 | Inc. 1, pasture soil |
| 8.41 | July 11 | July 31 | Aug. 25 | Sept. 22 | Oct. 11 | 92 | |
| 16.11 | July 19 | Aug. 5 | Aug. 23 | Sept. 22 | Oct. 11 | 84 | |
| 18.13 | July 21 | Aug. 8 | Aug. 26 | Sept. 22 | Oct. 11 | 82 | |
| 20.21 | July 23 | Aug. 9 | Aug. 26 | Sept. 22 | Oct. 11 | 80 | |
| 12.41 | July 15 | Aug. 9 | Aug. 29 | Sept. 23 | Oct. 12 | 89 | |
| 44.31 | Aug. 16 | Aug. 28 | Sept. 6 | ——— | Oct. 12 | 57 | Inc. 1 |
| 10.41 | July 13 | July 31 | Aug. 25 | Sept. 23 | Oct. 13 | 92 | |
| 17.21 | July 20 | Aug. 10 | Aug. 28 | Sept. 24 | Oct. 14 | 86 | |
| 15.21 | July 18 | Aug. 4 | Aug. 29 | Sept. 24 | Oct. 14 | 88 | |
| 8.21 | July 11 | July 29 | Aug. 21 | Sept. 24 | Oct. 16 | 97 | |
| 14.21 | July 17 | Aug. 7 | Aug. 27 | Sept. 26 | Oct. 21 | 96 | |
| 13.41 | July 16 | Aug. 7 | Aug. 28 | Sept. 27 | Oct. 22 | 98 | |
| 8.52 | July 11 | Aug. 1 | Aug. 26 | Sept. 27 | Oct. 23 | 104 | |
| 12.21 | July 15 | Aug. 5 | Aug. 26 | Sept. 27 | Oct. 23 | 100 | |
| 13.42 | July 16 | Aug. 7 | Aug. 30 | Sept. 29 | Oct. 25 | 101 | |
| 21.11 | July 24 | Aug. 10 | Sept. 1 | Sept. 28 | Oct. 25 | 93 | |

[5]Inc. = Incubation.

When ready to pupate the larva constructs an earthen cell, the larval skin loosens, and splits along the back. A few pupae remained in the larval skin that had failed to split, and these failed to live through the pupal period.

For 42 pupae the period ranged from 10 to 31 days, with an average of 17.8 days. The ten-day records are from incubators with temperatures of 31–35 C. degrees; 12 days was the shortest pupal period in the pit. In our methods of rearing the pupa seems to be the most sensitive stage; a much greater proportion of pupae than of larvae succumbed to various unfavorable conditions. It seems that this fact could be made useful in devising control measures.

A total of 50 adults were reared. Leaving out six which had to be brought indoors on account of cool weather, the combined larval and pupal periods ranged from 51 to 104 days (see Table 3). For the larvae and pupae kept in incubators the time required ranged from 51 to 57 days. Those in the pit required from 69 to 104 days. Adding 12 days, the average time required for hatching, the total period from egg to adult is 81 to 116 days. Since the life history studies were begun somewhat late (the first hatching occurred early in July) so that no adults emerged until after the middle of September; while in the field adults are probably emerging throughout the greater part of August; the developmental period for many individuals in the field is probably somewhat shorter.

Attempts were made to rear some of the larvae in the heavy loam (used in making up our mixture) alone. The larvae grew very slowly and but one individual out of seven lots emerged as an adult. This was reared in the incubator and during the third instar was shifted to the soils mixture with corn.

Adjournment 3.05 p. m.

*Thursday Morning Session, December 31*

The session convened at 10.15 a. m., R. W. Harned, Chairman of the Cotton States Branch presiding.

CHAIRMAN R. W. HARNED: The first part of the morning session is a joint meeting between the general Association and the Cotton States Branch.

CHAIRMAN R. W. HARNED: We will now hear a paper by S. Marcovitch and W. W. Stanley.

# EXPERIMENTS ON THE CONTROL OF ARSENICAL INJURY ON PEACH

By S. MARCOVITCH and W. W. STANLEY, *Tennessee Agricultural Experiment Station*

ABSTRACT

It is now generally believed that arsenic poisons the cell through its reaction with the SH group of glutathione. Since this material is closely allied with the growing process, nitrogenous fertilizers were used to stimulate growth in the hope of overcoming arsenical spray burn on peach. On poor soils, on which the injury from lead arsenate was most severe, the least "burning" was encountered where nitrogen was used.

The question of foliage injury resulting from the use of chemicals for the destruction of insect pests has always been puzzling. This is especially true in the case of lead arsenate on peach. In New Jersey Haensler and Martin (1925) claimed that lead arsenate was the cause of premature defoliation and of canker formation on new and one year old wood. On the leaves the injury appears as brown circular necrotic areas, or a narrow strip of dead tissue along the leaf margin. When these dead areas fall away a shot hole appearance is caused that may be mistaken for the bacterial leaf spot.

As a precaution against arsenical injury on peach, only three lead sprays are recommended, although these may not be sufficient for the most effective insect control. In a general way, the water-soluble arsenic was known to be the principal cause of burning. All efforts were therefore directed toward its elimination in the manufacture of lead arsenate. To reduce the injury to a minimum, correctives, such as lime, gypsum, and ferric oxide, have been recommended to be added to the spray material.

But in spite of the wide use of large quantities of lime in peach spraying, foliage injury is continually encountered. Swingle (1929) has shown that the soluble arsenic can not be sufficiently reduced to prevent foliage injury, for as little as .04 per cent arsenic pentoxide caused severe injury. In 1930, we obtained severe foliage injury at Kingston, Tennessee, with four lead sprays, while the same number of sprays in a peach orchard at Knoxville was not noticeably injurious. In the Kingston orchard the trees in the outside row, adjoining a fence grown up with weeds, were not as badly defoliated as those trees in the center of the block. All the external factors, such as temperature and rainfall, appeared similar in the two cases. The internal factors or the resistance of the trees must have been widely different to produce such a marked discrepancy. If the mechanism whereby arsenic poisons a tree were known, it should be

possible to overcome the so-called "burning". Since much progress has recently been made in elucidating the mechanism of arsenical poisoning on animal tissues, the application of this knowledge to plant physiology may profitably be undertaken.

LITERATURE. In a general way it is known that arsenicals hinder oxidation and interfere with the normal course of respiratory metabolism. The true nature of the chemical combination of arsenic with some particular substance in the cell is being gradually revealed. In 1921 Hopkins demonstrated that the cell constituent, glutathione, is concerned in biological oxidation and reduction. Glutathione is a "protein-like" substance which contains the sulphydryl amino-acid cystein. The sulphydryl group (-SH) readily changes to the oxidized form (-S-S-). This reaction is reversible, glutathione serving either as a hydrogen or oxygen acceptor and in this way promoting cell oxidations.

Voegtlin, Dyer and Leonard (1923) mention the fact that in qualitative and quantitative analyses use is made of the great reactivity of arsenite with $H_2S$, and consider it logical to suspect that arsenic might react with a protoplasmic constituent containing sulphur. After subjecting this hypothesis to experimental proof, these authors conclude that arsenic would poison the cell through its reaction with the SH group of glutathione, thus interfering with the mechanism of cell respiration. They were also able to counteract the effect of arsenic by the proper injection of sodium thioglycollate and other SH compounds.

Working with insects, Fink (1927) showed that those species subjected to arsenical treatment gave marked reduction in their glutathione content, indicating that glutathione is an arsenical receptor.

Hammett (1930) showed that glutathione is closely allied with growth. It is always present in abundance where rapid production of new tissue is in progress. Growth by increase in cell number was stimulated by substances containing the sulphydryl group. By the use of thioglucose, healing of wounds was promoted.

With advancing age there is a progressive diminution in the resistance to arsenic, for a dose of 11 mg. per Kilo of $AS_2O_3$ is fatal to rats 60–90 days old, whereas only 8 mg. per Kilo is fatal to rats 210–240 days old (Hammett and Nowrêy, 1921).

EXPERIMENTAL. The literature cited above indicates that arsenic reacts with the sulphur of glutathione and similar compounds. Since these compounds are necessary for growth and are most abundant where growth is rapid, a young, vigorous, rapidly growing organism should tolerate arsenic better than a mature organism.

The logical method of inducing growth and vigor in a tree is by ferti-

1

2 3

1. Right: Peach trees defoliated by four lead arsenate sprays with no fertilizer treatment. Left: Trees with the same spray treatment but fertilized with sodium nitrate. Photograph taken August 12, 1931; 2. Twig from sprayed unfertilized tree on October 9, 1931 showing complete defoliation, dead buds and new growth; 3. Twig from sprayed fertilized tree showing partial defoliation but no new growth.

lization. We therefore selected the trees at Kingston, Tennessee, that were injured by arsenic in 1930 and applied different fertilizer treatments, as shown below.

TABLE 1. THE INFLUENCE OF FERTILIZER TREATMENTS ON FOLIAGE INJURY PRODUCED BY LEAD ARSENATE AND FLUORINE SPRAYS

| | Kind of fertilizer | Total application in lbs. per tree |
|---|---|---|
| 1. | Sodium nitrate | 7.5 |
| 2. | Ammonium sulphate | 6.0 |
| 3. | Calcium nitrate and Ammonium sulphate | 3.0<br>3.6 |
| 4. | Sodium nitrate<br>Acid phosphate<br>Muriate of potash | 7.5<br>15.0<br>4.8 |
| 5. | Manure | 125.0 |

In order to be sure of sufficient rainfall to carry the fertilizers down, one application was made in the late fall, December 19, 1930. The remainder was applied on March 23 and April 23, 1931. The phosphate and potash were spaded into the soil, while the other treatments were applied on the surface. The regular spray schedule, consisting of three lead sprays, was applied, but to some of the trees four were given. Applications of spray material were made April 23, May 5, June 3, and July 8, 1931.

Examined on May 25, after two sprays had been applied, no foliage injury was apparent, although the fertilized trees looked greener than those without fertilizer. By June 3, Plot 3, receiving lead arsenate and Cal-Mo-Sul, began to show signs of defoliation. Plot 4, having lead arsenate and flotation sulphur and lime, began to show injury on July 8. At this time, the fertilized trees were holding their leaves somewhat better. By July 28, the difference in foliage injury was more pronounced, and on August 12 a marked difference was noted between the fertilized and unfertilized trees. The former were vigorous looking, with the foliage and fruit green, as shown in Plate 7, Fig. 1, while the unfertilized trees were almost completely defoliated and fruit ripe and ready to pick. Yet the two lots received the same number of lead arsenate sprays, four altogether. The lack of foliage in the unfertilized plots caused considerable "sun scald" on the prematurely ripened fruit. An examination of the trees was also made August 28. The difference between the fertilized and unfertilized trees on this date was not as striking as on August 12, for a new crop of leaves began to appear on the unfertilized trees, as shown in Plate 7, Fig. 2. Nevertheless the inherent injury

to the trees was perhaps greater, for the production of a new crop of leaves at this season is always detrimental to the following crop of fruit. In the fall of 1930, the plots defoliated by lead arsenate were in the process of flowering. Late in the season some burning and defoliation were observed on the fertilized trees. The total effect did not appear serious because of the continual production of new growth and leaves (Pl. 7, Fig. 3).

One of the interesting things noted in the fertilizer treatments is that no difference could be observed from the various applications. Apparently nitrogen is the only element needed to give a good growth response. This is in accord with the experience of the practical growers who use nitrogen fertilizers only.

Three sprays of Cal-Mo-Sul (calcium sulphide) and lead arsenate also produced defoliation. This was probably due to an incompatibility, resulting in the formation of soluble arsenic.

Ginsburg (1930) recommended ferric oxide and skim milk to be mixed with the lead arsenate for avoiding arsenical burning. Some of the trees were sprayed according to his directions, but the ferric oxide did not prevent burning.

Four cryolite treatments at the rate of one pound to fifty gallons produced no foliage injury. Barium fluosilicate (Dutox) was almost as safe as the cryolite. In the experimental work of 1930, these fluorine compounds were also found safe on peach foliage (Marcovitch and Stanley, 1930).

Comments. A survey of the literature on arsenical injury of peach points to the states of New Jersey and Georgia as being most concerned. The soils of these states where peaches are grown are predominantly sandy. Sandy uplands are usually poor in nitrogen and other nutrients necessary for growth and vigor. Although commercial fertilizers are used in these areas, a tree grown on a sandy soil seldom has the appearance of one grown on a rich soil with an abundance of nitrogen. The soils at Kingston, Tennessee, where spray burn has been encountered are known to be low in fertility.

Recently, Paden and Albert (1930) noted that the sandy soils in South Carolina become unproductive when preceded by cotton crops that have been dusted with calcium arsenate for the control of the boll weevil. The addition of calcium hydroxide to the "arsenic-sick" soils aided in overcoming the trouble, probably because the lime decreased the solubility of the arsenic in the soil. To determine just what effect the addition of an adequate supply of nitrogen to these unproductive soils would have, might be an interesting experiment. It is not to be inferred that the use of nitrogen will, by increasing growth, overcome all

types of arsenical injury. Yet the evidence points to the conclusion that when the water-soluble arsenic is reduced to a minimum, other factors being equal, increased vigor and growth will help a tree to overcome arsenical injury when it might otherwise have succumbed. The natural antidote for arsenical injury is an abundance in the leaf tissues of SH groups such as are found in glutathione, thioglucose and cysteine. Just how these materials would act as correctives when added to the spray material is problematical. It is to be regretted that no quantitative data were obtained in regard to the abundance of glutathione in the sprayed and fertilized trees as compared with the unfertilized.

SUMMARY. In 1930 severe defoliation by four lead arsenate sprays was encountered at Kingston, Tennessee. The same spray schedule at Knoxville did not produce "burning". Since the soils at Kingston are poor in fertility, a series of experiments were carried out to test the effect of fertilizers in overcoming arsenical spray injury.

In all cases where the nitrogenous fertilizers were used the arsenical injury was reduced to a minimum as compared with that on the unfertilized trees. The hypothesis is advanced that a tree showing increased growth is well supplied with an abundance of SH groups which are believed to be the natural antidotes for arsenical poisoning.

## LITERATURE CITED

1. FINK, D. E. Is Glutathione the Arsenic Receptor in Insects? Jour. Econ. Ent. 20: 794. 1927.
2. GINSBURG, J. M. Studies with Hydrated Ferric Oxide as Corrective and Sticker for Lead Arsenate and Nicotine Tannate. Jour. Econ. Ent. 24: 695. 1931.
3. HAMMETT, F. S. The Natural Chemical Regulation of Growth by Increase in Cell Number. Proc. Am. Philosophical Soc. 69: 217. 1930.
4. HAMMETT, F. S., and NOWREY, J. E. Changes with Advancing Age in the Resistance of the Albino Rat to Arsenic. Jour. Phar. and Expt. Ther. 19: 331–335. 1921.
5. HAENSLER, C. M., and MARTIN, W. H. Arsenical Injury of the Peach. Phytopathology 15: 321. 1925.
6. HOPKINS, F. G. On an Autoxidisable Constituent of the Cell. Biochem. Jour. 15: 286. 1921.
7. MARCOVITCH, S., and STANLEY, W. W. A Preliminary Report on Arsenical Substitutes for Peach Spraying. Jour. Econ. Ent. 24: 844. 1931.
8. PADEN, W. R., and ALBERT, W. B. Effect of the Addition of Arsenical Compounds to Soils. S. C. Exp. Sta. 43rd Rpt. p. 31. 1930.
9. SWINGLE, H. S. Composition of Commercial Lead Arsenate and its Relation to Arsenical Injury. Jour. Agr. Res. 39: 373. 1929.
10. VOEGTLIN, C., DYER, H. A., and LEONARD, C. S. The Mechanism of the Action of Arsenic upon Protoplasm. Public Health Report, U. S. Pub. Health Ser. 1923.

CHAIRMAN R. W. HARNED: The next paper is by Dwight Isely and H. H. Schwardt.

## THE RICE WATER WEEVIL PROBLEM IN ARKANSAS[1]

By DWIGHT ISELY and H. H. SCHWARDT, *University of Arkansas*

ABSTRACT

The rice water weevil (*Lissorhoptrus simplex* Say) occurs in large numbers in all rice fields in Arkansas, and is the only generally distributed pest of this crop in this region. The larvae feed on the roots of rice and are frequently charged with causing great damage. In large cage experiments the yield of rice in uninfested cages was approximately 35 per cent greater than it was in cages artificially infested. The loss caused by this insect may be reduced by drainage, at the time the majority of the larvae have entered the third instar and before severe root pruning begins. Drainage should continue until the soil is thoroughly dried.

The rice water weevil[2] is the only rice feeding insect which is generally distributed every year throughout the Arkansas rice belts. During every season since the species has been under our observation, weevils have been found in every field visited, and usually they were abundant. Because of their ubiquity, water weevils and their larvae, popularly known as "maggots", are often charged by growers with short yields and killing of stand when they are in no way connected with the damage in question. It is an important part of the problem to determine as definitely as possible the destructiveness of this insect, since control by drainage as is usually recommended is complicated by a number of factors including control of weeds and diseases, and water costs.

That the importance of the rice water weevil was over-estimated was first suggested by Ingram.[3] Later Ingram and Douglas[4] published results of a series of cage experiments which showed that the weevil was of no importance in Louisiana. The problem in Arkansas[5] is somewhat different from that in Louisiana. According to our counts, weevils are

[1]Research Paper No. 260, Journal Series, University of Arkansas.

[2]*Lissorhoptrus simplex* Say, order Coleoptera, family Curculionidae.

[3]Ingram, J. W. Insects injurious to the rice crop. U. S. D. A. Farmers' Bul. 1543. 16 p., illus. 1927. *L. simplex*, p. 4–8.

[4]Ingram, J. W. and W. A. Douglas. Damage by the rice water weevil proved negligible. La. Agr. Exp. Sta. Bul. 214. 8 p. 1930.

[5]The studies reported in this paper were carried on largely in 1930 and 1931, at the Rice Branch Experiment Station at Stuttgart, Arkansas, although some records date back to 1928. The writers are indebted to William R. Horsfall for assistance in 1930, and to C. B. Gilliland for assistance in 1931; and also to G. H. Banks, Assistant Director of the Rice Branch Experiment Station, for cooperation throughout the entire period.

present in rice fields in Arkansas in larger numbers than in Louisiana. It is perhaps unusual for an insect to be more numerous in a northern crop belt than in one of a more southern latitude. This may be explained by the fact that the rice water weevil is a temperate zone insect, with its northern range extending from New England to Michigan and into Canada.[6] Rice, a tropical plant, is one of the hosts of this weevil only where the range of the insect and of the plant overlap. It is quite likely that the optimum climatic condition for the rice water weevil is distinctly north of the optimum for the rice plant.

Adult abundance was determined by dropping a screen cage two feet square over rice plants and counting the adults thus enclosed. Five such counts were made at one time in each plot. The earliest count was made during the first week following flooding, and successive counts were made at intervals of one week in all plots continuously flooded.

The highest average infestation found in any plot was 14 weevils to a square foot. The average infestation of eighteen plots, during the first week after flooding, was 6.7 weevils to a square foot. In only three plots was the average less than 5 weevils to a square foot. The maximum found in Louisiana was 2 weevils to a square foot.

Cage experiments were also used to determine the extent of damage, if any, caused by the species, and to check on the data from field plots. The methods used by Ingram and Douglas[7] in determining the economic importance of the rice water weevil were followed in part, and in this we were aided by suggestions from Mr. Douglas. Cages 8 feet long, 6 feet wide, and 4 feet high, covered with wire screen with 18 meshes to the inch, were placed just before flooding in plots to be continuously flooded. As soon as the plots were flooded, weevils were introduced in half the cages. The remaining cages were not infested. The number of weevils placed in the majority of the cages was the average number found in the field plots at the same time. Cages were placed in early plots of rice flooded May 30; in midseason plots flooded June 17; and in late plots flooded July 17. A total of seven pairs of cages was used. None of the cages were strictly uninfested. At first an attempt was made to remove all weevils found in "uninfested cages", but on account of trampling of rice this was discontinued. The smaller weevils could work through the 18-mesh screen, and hence some larvae were found among the roots of rice in all cages. Nevertheless the cages were to a large degree effective.

[6]Blatchley, W. S. and Leng, C. W. Rhyncophora of North Eastern America. 682 p., illus. 1916. *L. simplex*, p. 229.

[7]Ingram, J. W. and W. A. Douglas. Damage by the rice water weevil proved negligible. La. Agr. Exp. Sta. Bul. 214. 8 p. 1930.

In all cages but one the yield of rice was at least 25 per cent greater in the uninfested cages than in the infested cages. The average yield of the seven infested cages, computed on an acre basis, was 1714 pounds; of the seven uninfested cages, 2315 pounds, or an increase of 35.1 per cent.

The seasonal history of the rice water weevil in a given field begins with flooding. Rice fields are invaded by swarms of adult weevils immediately after flooding. As a rule, weevils are most abundant during the first week after rice is flooded and then gradually decline in numbers for five to six weeks, when there is a sudden increase in numbers. This increase probably represents a newly matured generation. Within eight days after flooding, in June or July, larvae of the first instar are found among the roots. These larvae pass to the second instar within about three days and to the third instar within three or four days more. Cocoons have been found within twenty-three days after flooding, and pupae within twenty-six days after flooding. The pupal period may be as brief as seven days.

The heaviest feeding is by larvae of the third instar. When the larval infestation was at its height in our plots, the average infestation was seldom less than 10 larvae to a plant. More than 40 larvae were occasionally washed from individual plants. The average number of larvae to a plant in plots of late rice in mid-August, 1930, was 16.6. Where there are large numbers of larvae of the third instar, the number of smaller larvae is relatively insignificant. Within three to four weeks after flooding, the number of larvae feeding among the roots declines, since many spin cocoons. Within six or seven weeks after flooding, larvae of the first and second instars again occur in large numbers, and this is followed by a second period of infestation, suggesting a second generation. Some larvae may be found in the fields until September. The late larvae cause no serious root pruning, since the plants have apparently outgrown the possibility of such injury. Serious injury apparently is caused only by the early larvae which appear soon after flooding, and most of this injury probably occurs between the third and fifth weeks.

Drainage of rice fields is the measure which has been recommended for many years for the control of the rice water weevil.[8,9] This practice is undoubtedly effective in destroying the larvae feeding among the roots, although the destruction is not complete. In our experiments in

[8]Tucker, E. S. U. S. Bur. Ent. Circ. 152. 20 p., illus. 1912.

[9]Webb, J. L. How insects affect the rice crop. U. S. D. A. Farmers' Bul. 1086. 9 p., illus. 1920. *L. simplex*, p. 2–6.

1931, approximately 75 per cent of the larvae were killed. As commonly practiced, however, drainage is often of doubtful value. Drainage gives an advantage to the competing grass growing in rice fields. Also, as a result of drainage, reflooding is necessary, which adds to the water costs. Possibly there are other agronomic disadvantages.

TABLE 1. *Lissorhoptrus simplex*. COMPARISON OF AVERAGE YIELDS IN EARLY DRAINED, LATE DRAINED, AND UNDRAINED CHECK PLOTS. STUTTGART, ARK., 1930

| Plots | Number of plots | Average yield per acre (computed) | Percentage of yield of plots |
|---|---|---|---|
| Check plots..... | 6 | 4265.83 lbs. | 100.00% |
| Early drained plots... | 5 | 4536.69 lbs. | 106.35% |
| Late drained plots.... | 6 | 4922.57 lbs. | 115.35% |

Field plot experiments were conducted at the Rice Branch Experiment Station in 1930 and 1931, to determine the best time for drainage of infested fields and the length of the period of drainage. In 1930, two series of plots were used, one series being sowed about the average date for the region and the other series representing late seeding. In 1931, three series were used, one being early, one mid-season, and one late. Each plot covered one-tenth of an acre. Yields computed for each plot were based on five square yards, taken in five locations in each plot, in a manner similar to that employed in Hessian fly investigations by the Bureau of Entomology. In the plots under consideration in this paper a single variety, Supreme Blue Rose, was used.

It is obvious that to secure the best results, control measures should be applied before the heaviest feeding occurs and at the time when the greatest number of larvae can be destroyed. In 1930 early and late drainage were compared. Early drainage was applied about 14 to 18 days after flooding when larvae of the third instar were first appearing and before root pruning was much in evidence. Late drainage was applied when most of the larvae were in the third instar, and after root pruning was beginning to be apparent. The late drainage was about 21 to 24 days after flooding. The yields on the late drained plots were in all cases higher than those of the undrained check plots, and were consistently higher than those of the early drained plots, as is shown in Table 1.

In 1931 the late drained plots also had an advantage, but one that was less distinct. During this season intermittent rains made long continued drainage necessary. Six plots were reflooded within two weeks after drainage. Eleven plots remained drained for 19 to 29 days,

or until the soil was dried until its moisture content was about 10 per cent. The difference in yield is shown in Table 2.

TABLE 2. *Lissorhoptrus simplex*. COMPARISON OF LONG DRAINED, SHORT DRAINED, AND UNDRAINED CHECK PLOTS. STUTTGART, ARK., 1931

| Plots | Number of plots | Average yield per acre (computed) | Percentage of yield of checks |
|---|---|---|---|
| Check plots..... | 8 | 2137.5 lbs. | 100.00% |
| Short drainage..... | 6 | 2265.5 lbs. | 106.00% |
| Long drainage..... | 11 | 2435.6 lbs. | 113.94% |

At this point the meeting was turned over to President J. S. Houser who called on Mr. Oliver I. Snapp to make a statement.

Mr. Snapp announced that the regular annual meeting of the Cotton States Branch will be held at Birmingham, Alabama, February 3 and 4, and extended an invitation to all entomologists to attend.

PRESIDENT J. S. HOUSER: I find that Doctor J. H. Hawkins and Mr. Lee A. Strong, have been unable to attend the meeting and the invitation papers will be given by W. B. Herms and by W. C. O'Kane.

I will now call on W. B. Herms to present the first paper.

## INSECT PARASITOLOGY

By W. B. HERMS, *Professor of Parasitology, University of California, Berkeley, Calif.*

ABSTRACT

The study of insect parasitology offers much of interest to workers in the various fields of entomology such as anatomy, taxonomy, histology, ecology, physiology, and toxicology. An understanding of the sucking mechanism with its chemical products and the effect of these on animals as well as on plant tissue is a matter of prime importance. The problem of host specificity and host range are matters of concern to both medical entomology and biological control. The study of insect parasitology becomes most significant in relation to the transmission of micro-organisms pathogenic to animal and plant life. This relationship remains incomplete without a knowledge of reservoir animals and plants. The curricular requirements for adequate training in the field of insect parasitology are not now met through the channels of entomology alone. The insect parasitologist should first of all be a fundamentally well trained biologist.

The objective in the study of insect parasitology will, of course, vary with the viewpoint of the interested worker. The anatomist, the taxonomist, the ecologist, the physiologist, the pathologist, the toxicologist, each will find many interesting problems in this field. Insect parasites and parasitoids offer a fruitful array of organisms for the study of mechanisms which enable these animals to procure sustenance and otherwise to live under other than so-called free living conditions. The suck-

ing mechanism of both phyto-succivorous and haematophagous insects and arachnids offers much of interest to the student of anatomy.

A comparative study of this nature demands a superior knowledge of arthropod mouth parts in general and in addition facility in handling intricate morphological and histological technique. To fully comprehend the effect of this mechanism and its accessories on the host, a matter of more than passing interest to the parasitologist, other fields of study are immediately involved. The morphologist needs perhaps go no further to satisfy his interest in the mechanism. However, the understanding of parasitological relationships requires also histological study,—a knowledge of both the plant and animal tissues which are affected by the sucking mechanism and its chemical products. Chemistry can make a real contribution at this point in the study of insect toxins and other products of the alimentary mechanism. How these chemical products of the parasite affect living tissue of the animal or plant host is a matter of no small importance.

No doubt some of our economic entomologists are beginning to wonder at the audacity of the writer in his allusion to phytophagous insects and their plant hosts in a paper dealing with insect parasitology. This procedure appears to me to be perfectly logical, however, it does not follow that every economic entomologist should be a parasitologist, although training in the field of parasitology would appear to be very valuable. I do feel that the insect parasitologist does possess certain abilities and experiences which are of value in the field of economic entomology as a whole, and particularly in relation to biological control. I am, therefore, not limiting this discussion to the insect parasites commonly included within the scope of parasitology, and furthermore the term insect is here interpreted as in economic entomology, i. e., inclusive of the arachnids and some other related arthropods.

Morphological Convergence. As one contemplates the morphology of arthropod parasites one is tempted to inquire into the question of morphological unity or convergence It is fair, I assume, to ask: Is there any one structure or any set of structures which all parasites possess? Does parasitism tend to develop structures of a given type?

Anatomically, I believe, it would be difficult to establish a set of structural specifications for an arthropod parasite, perhaps less difficult to erect a set of physiological specifications. It might be worth trying! Can one know by simple examination whether or not the specimen at hand is or is not a parasite? Should the parasitologist be expected to know this? Perhaps the insect anatomist and embryologist will help us in this matter,—or should we look more particularly to the taxonomist?

Thompson and Parker (Etudes sur la biologie des insectes parasites : la vie parasitaire et la notion morphologique de l'adaption. Ann. Soc. Ent. Fr., vol. XCVI, pp. 113–146, 1927) among others have struggled with this problem more or less successfully. They believe that a closer anatomical study would show the deeper morphological unity. The sum of adaptive characters reveals a degree of morphological unity. Taxonomic characters only mask the adaptive characters according to these authors. To those interested in this phase of our subject, the writer calls attention to a paper presented at an earlier meeting of this Association under the heading of "The effects of parasitism on the host and on the parasite." (Herms, Jour. Econ. Ent., vol. 19, no. 2, pp. 316–325, 1926.)

PARASITIC SPECIFICITY. In the study of parasitology the host-parasite relationship is, of course, all important, it is the essence of our subject: What constitutes an ideal host and, if you please, an ideal parasite? From the viewpoint of biological control Thompson and Parker (Parasitology, vol. XIX, no. 1, pp. 1–34, 1927) in "The problem of host relations with special reference to entomophagous parasites" state the matter thus: "If we could define in a scientific manner the exact nature of the attraction exerted by a host upon its parasites the whole treatment of parasitological problems would be enormously simplified and facilitated. It would then be possible to predict what hosts a given species would attack in any region. We could thus estimate the probable action of a parasite introduced experimentally into a new country and foretell the rôle of native parasites in relation to pests imported from abroad. To arrive at such a result it would be necessary to determine exactly what group of qualities exerts the maximum attraction on the parasite. Having thus defined what might be called the *ideal host* of the parasite, one would attempt, by means of a detailed analysis of their specific characteristics, to assign values to the other available hosts. To complete the investigation it would be necessary to determine not only the qualities by virtue of which the host attracts the parasite, but also what characteristics the parasite must present to be susceptible to the attraction. In other words, one would have to define not only the 'normal' host of a given parasite, but also the 'normal' parasite of a given host."

That Thompson and Parker (loc. cit.) consider the solution of this problem a very difficult one is indicated by the following quotation: "The general conclusions of our investigation are that the problem of host relations or, as it it sometimes called, of the specificity of parasitism, is not one susceptible of any general solution in scientific terms. . . . there is no reason to believe that these factors (main factors involved in the

attraction exerted upon a parasite by a given species of host) are the same for all the hosts attacked or that it is possible to define in terms of physico-chemical or morphological characters the 'ideal' or 'typical' host of a given parasite. As for the idea of defining the 'ideal' or 'typical' parasite of a given host, it is a fallacy."

In spite of the fact that Pearse (The ecology of parasites, Ecology, vol. VII, no. 2, pp. 113–119, 1926) remarks that "A knowledge of ecology is the logical basis for procedure in attempting to foster or exterminate a parasite," Thompson and Parker (loc. cit.) believe "it would be unwise to rely too much on ecological studies in practical work of the type described. Experiment alone can supply an answer to the questions involved in such problems."

Host Range. A knowledge of host range may have great practical value as you all know. This is not only true particularly in biological control operations but also in the field of medical entomology. There are, for example, mosquitoes that feed only on cold blooded animals as seems to be the case with *Culex apicalis* Adams (also sometimes referred to in the literature as *Culex testaceus* Van der Wulp) and is not known to bite man. *Culex erythrothorax* Dyar, a California species is believed to confine its feeding activity to birds. The adult megarhine mosquitoes are known to be phytophagous while the larvae are predaceous. *Megarhinus inoratus* Wlk. was recently introduced into Hawaii. The introduction of this species as a control factor has been disappointing, we are told, perhaps largely because it does not breed in the situation where the mosquito pests originate. An ecological study of this species in its native habitat might be of some value. Perhaps that was done before its introduction.

Of even greater practical value in relation to medical entomology is a knowledge of the host range of such insects as anopheline mosquitoes, for example, some of which are distinctly zoophilous and consequently of little or no importance as malaria vectors. The possibility of transfer of affections must, however, always be borne in mind. Paucity of the so-called normal animal hosts might result in such a transfer.

The causative micro-organisms of certain insect-borne diseases heretofore linked to specific insect vectors are now known to have a wider host range. In most of these instances, however, this range is rather narrow and limited to fairly closely related species.

As already intimated, a knowledge of host range is of particular significance in relation to the parasitoid entomophagous insects as employed in biological control operations. No student of insect parasitism will neglect to read the last four chapters of Imm's "Recent ad-

vances in entomology." In the introduction of an entomophagous insect for a specific purpose, for example in the control of the black scale, *Saissetia oleae*, it is important to know whether or not it is monophagous. So far as known, *Aphycus lounsburyi* How. is specific to the black scale, as is *Tetracnemus pretiosus* Timb. to *Pseudococcus gahani*, and *Pseudleptomastix squamulata* Gir. to *Pseudococcus maritimus*, and *Pseudaphycus utilis* Timb. to *Pseudococcus nipae*. The latter is known as the avocado mealybug and its control in Hawaii by means of the aforementioned encyrtid wasp from Vera Cruz is regarded as one of the several outstanding achievements in biological control.

In a recent letter to the writer, Professor H. S. Smith replies to my inquiry concerning monophagous parasitoids as follows: "Of course it is always possible that these supposedly specific parasites may on further study prove to be polyphagous. That has been true in a good many cases. I think it is more generally true that insect parasites are limited in their host relations to rather closely knit groups of species, rather than to a single species, although there are undoubtedly many truly specific parasites . . . . Specificity in many cases is only apparent because of insufficient knowledge of the biology of the species."

Vectors of Pathogenic Organisms. The study of insect parasitology becomes most significant in the realms of human and veterinary medicine and plant pathology. A considerable number of important human, animal, and plant diseases are now known to be transmitted by arthropods. How insects and their kin become vectors of pathogenic organisms is an interesting question to contemplate. In some instances at least it is quite reasonable to believe that the causative organisms of certain diseases such as the spirochaetes, flagellates and rickettsia bodies were originally merely symbionts in the bodies of their arthropod hosts and through favorable association of these hosts with vertebrated animals became pathogenic. Perhaps pathogenic relationships between causal agent and vector have arisen similarly in the higher plants. It seems equally clear that some of the insect-borne diseases have had their origin from unicellular parasites or symbionts of plants and later became symbiotic in arthropods which fed on these plants and through a change from the phytophagous habit to a haematophagous habit in turn became not only parasitic in the new host, but also violently pathogenic,—pathogenic because of ill adaptation. As the newly acquired parasites become better adapted to the new host, pathogenicity becomes less and less marked until a degree of symbiosis is achieved, when the host becomes a reservoir animal. A state of perfect symbiosis would probably never be achieved, in which case the invaded animal (the host) would

eventually be entirely immune to the effects of the invader. On the other hand, the invaded animals might suffer complete annihilation because of the violent effects of the invader,—neither a symbiont nor a good parasite. Nuttall in his presidential address (1923), "Symbiosis in animals and plants," delivered before the British Association Section on Physiology, states the matter, viz.:

"In perfect symbiosis the associated organisms are completely adapted to a life in common. In parasitism the degree of adaptation varies greatly; it may approach symbiotic conditions on the one hand, or range to vanishing point on the other by leading to the death of the organism that is invaded by a highly pathogenic animal or vegetable disease agent. There is no definite boundary between symbiosis and parasitism. The factors governing immunity from symbionts or parasites are essentially the same.

"No final conclusions can as yet be reached regarding the function of symbionts in many invertebrate animals owing to our ignorance of the physiological processes in the associated organisms. The investigation of these problems is one fraught with difficulties which we must hope will be surmounted."

The Hemiptera will no doubt come to mind as good examples of insects that originally fed on the sap of plants and in the main have continued to do so. Root (Parasitism among the insects, The Scientific Monthly, vol. IX, pp. 479–495, 1924) expresses this idea in the following words, ". . . in order to obtain this (plant sap) the bugs have developed a very effective piercing and sucking beak. Some of the Hemiptera, the majority of the Reduviidae, for example, have discovered that this beak will serve equally well to extract juices from smaller insects, and have thus become predaceous. And, finally, a few reduviids, such as the species of the genera *Triatoma* and *Rhodnius*, have found that still larger animals, the lower mammals, contain just beneath the skin and within easy reach of the hemipterous beak a nourishing fluid, the blood. Some of these species have even dared to transfer their affections to man himself, when opportunity served, unfortunately carrying with them the trypanosome parasites of their former hosts, which proved so ill adapted to the human body that they produced the disease discovered by Dr. Carlos Chagas, and often known by his name. Here we have the unusual spectacle of a change in feeding habit from plant parasitism, through a predaceous habit to parasitism on lower animals and finally on man, without any essential modification in the organs by means of which food is obtained."

This brings us to the topic of reservoirs in relation to insect-borne

diseases, but before we discuss that point, let us pause to ask one more question relating to the present topic.

To what extent insects or arthropods in general may continue to be factors in the origin of new diseases is perhaps after all merely an interesting matter for speculation. The following quotation from Chandler (Speciation and host relationships of parasities, Parasitology, vol. XV, no. 3, pp. 326–339, 1923) is, however, significant. "The Rickettsia-like organisms associated with these diseases (typhus fever, trench fever, Rocky Mountain Spotted fever, and possibly Japanese Flood fever) are found in abundance in the arthropod vectors, but organisms of the same type are found also in fleas, sheep ticks, bedbugs, and Mallophaga. Furthermore, in body lice which apparently have had no opportunity to become infected from either typhus or trench fever patients, these organisms have been found . . . . Whether or not trench fever existed before the war, certainly it was at best an obscure, little known infection of local distribution, both as regards time and space. To the writer the more probable explanation is that the sudden appearance of trench fever was due to the development of a strain of the normally harmless *Rickettsia pediculi* of lice which was capable of multiplication in human blood and that this physiologically new strain of the organism, under the ideal epidemiological conditions afforded by the war, became firmly established and more readily infectious by repeated passage through human beings and was then spread all over Europe by the movement of troops and the abnormal abundance of lice."

The number of complaints concerning the vicious biting habits of notonectids seems to be increasing. Swimming pools are at times positively unpopular because of these pernicious little "back swimmers". In the absence of appropriate food such as tadpoles, small fish and the like, these insects are turning to human beings whose skins are easily punctured and beneath which is an abundant supply of highly nutritious fluid in the form of blood. Perhaps we are now witnessing the development of a new vector of some disease not yet known. My only advice to the back swimmers is that they must tone down the severity of their bite. The successful vectors of disease almost without exception have a rather benign bite, witness the bite of *Anopheles maculipennis* as compared with that of a salt marsh species, *Aedes dorsalis*, or that of the body louse, *Pediculus humanus*, as compared with that of the bedbug or that of the Stomoxys fly.

Reservoirs. In the light of advancing knowledge we cannot overlook the importance of reservoirs in relation to insect parasitology. Commonly the direct effect of the insect parasite on the host is of secon-

dary or even of negligible consequence in contrast with the importance as a vector of a disease producing factor. This is true not only of animal diseases but of plant diseases as well. If the insect parasitologist is to have a well rounded knowledge of his field he must not neglect the subject of reservoirs.

Among the non-human reservoirs of disease I desire to mention only a few. Plague immediately comes to mind as a disease in which an insect parasite plays an important role and in turn the rat takes its place as a reservoir. Not all rats are of equal importance in this connection; thus the brown rat, *Epimys norvegicus*, because of its very habits, burrowing rather than climbing, is of less importance as the source of human plague infection than is the roof rat, *Epimys alexandrinus*, a climbing rat, and the black rat, *Epimys rattus*. The plague problem is made more complicated because of the fact that other wild animals have been added to the list of reservoirs, namely the California ground squirrel, *Citellus beechyi*, also according to Stallybrass, "The Principles of Epidemiology" (1931), such rodents of southeastern Russia as the susliks (*Citellus*) and jerboas (*Alactoga, Rhombomys*) from which it is said "have proceeded two of the most devastating epidemics that have afflicted mankind." At least three dozen species of mammals are cited as possible reservoirs of plague. This fact offers ample room for the study of the Siphonaptera, particularly in their taxonomic and biological relationships.

Rocky Mountain Spotted fever also has its wild animal reservoirs in the form of ground squirrels, woodchucks, badgers, and rabbits. Spirochaetal diseases of humans no doubt also have their reservoirs in part at least in animal hosts. Indeed, young porcupines have been found to harbor *Treponema hispanica* in northern Africa. The discovery of other wild animals, such as the armadillo and opposum, which may serve as reservoirs of the spirochaetal affections of both humans and domesticated animals is a matter of interest to all students of insect parasitology. Since spirochaetes are readily transmissible hereditarily in the tick vectors, the need for a large number of animal reservoirs may be less from the viewpoint of the spirochaete,—race preservation being less precarious.

Both spirochaetes and Rickettsia bodies show strong arthropod affinities and point to an earlier plant host, and it is more than likely that their ill adaptation to the human host accounts for their virulence, e. g., typhus fever, Rocky Mountain Spotted fever and African Relapsing fever and its sequelae.

True reservoir animals do not suffer from the disease the causative organisms of which they harbor. Recently Simmons, St. John and Reynolds in "Experimental studies of dengue" (Philip. Jour. Sci., Jan.–

Feb. 1931) have infected monkeys (*Macacus* spp.) through the bites of infective mosquitoes (*Aedes argenteus*) causing multiplication of the virus in their blood without producing recognizable symptoms, suggesting the conclusion that monkeys may be a natural reservoir of the virus in endemic tropical localities.

Many more examples of non-human reservoirs of insect-borne diseases might be cited (in this connection attention is called to the large number of references to animal reservoirs in the Review of Applied Entomology, Series B, for 1931), but before closing the subject under discussion let us examine the matter of reservoirs in relation to plant diseases. Curly top virus transmitted by the leafhopper *Eutettix tenellus* to sugar beets and more than 300 species and varieties of cultivated plants in California is harbored naturally by a number of wild plants such as *Erodium cicutarium* (Geraniaceae), red stem filaree, a most important wild host introduced from the Mediterranean; also *Monolepsis nuttalliana* (Chenopodiaceae), *Lotus strigosus* (Leguminosae), and *Phacelia ramosissima* (Hydrophyllaceae). In the cultivated areas of the San Joaquin Valley, California, a wild perennial exists known as Mexican tea (*Chenopodium ambiosioides*) which harbors the curly top virus under natural conditions and is believed to be of great importance as a reservoir. Also a large number of annual weeds growing in the cultivated areas have been found to be naturally infected with curly top, but since these weeds become dry in the autumn, they play no role in the overwintering of the virus. The usual devastating symptoms of curly top as manifested in the cultivated plants are not usually strikingly present in the naturally infected wild plants.

Recently a remarkable suggestion has been made by Maldonado reported in the Bulletin de la Societe Pathologie Exotique, vol. XXIV, no. 1, pp. 27–28 (Rev. Appl. Ent., vol. XIX, Ser. B, p. 112, 1931), that certain plants may act as reservoirs of the causal organism of Verruga, a disease of man, and that the species of Phlebotomus flies that transmit the disease may feed on the latex in them. It is also suggested that this would explain why these sandflies are so abundant during the rains (January to April) when this particular plant growth (*Jatropa basiacantha* and *Orthopterygium huancui*) is most luxuriant.

The subject of reservoirs must not be passed over without reference to the fact that the insect parasitologist will find a field of great usefulness in making surveys of the arthropod parasites of wild animals and conducting or assisting with infectivity experiments in which a knowledge of the biting habits of these parasites is invaluable; and finally, when control becomes feasible, a knowledge of the breeding habits is essential. Thus

our insect parasitologist finds himself right in the midst of a practical application of taxonomy and biology involving field experience often of the roughest kind.

REMARKS. No doubt to most of us, perhaps to all, this discussion appears to drift far afield, yet few who now work or have worked in the field of insect parasitology will deny the propriety of the several phases discussed all too briefly in this paper. Other phases that occur to you and perhaps still others that come to my mind might have been discussed just as appropriately, or even more so.

The study of excretions and secretions of parasitic insects both in relation to the effect on micro-organisms and the host might well be emphasized. The coxal fluids of ticks should receive some attention on the part of the biochemist and the physiologist. Many of our blood-sucking insects exude per anum a droplet of clear fluid at the beginning of the feeding period, a phenomenon no doubt related to the preceding. A comprehensive study ought to be made of the relation of arthropods to diseases of fungus origin.

The astonishing announcement has been made by the Rockefeller Foundation (Annual Report 1930) that a dilution of between one ten-millionth (0.000,000,1) and one billionth (0.000,000,001) of one cubic centimeter of yellow fever virus has frequently proved fatal to monkeys and that infection through the unbroken skin is readily accomplished. Is there any one in this audience who does not have a profound respect for those scientists who are devoting themselves to a study of yellow fever, a disease transmitted by a mosquito!

As curricula are now constituted a student cannot secure adequate training as an insect parasitologist through the channels of entomology alone. Perhaps we are asking too much of entomology. After all, "a consideration of parasitism," as stated by Stunkard (Parasitism as a biological phenomenon, The Sci. Mthly., vol. XXVIII, pp. 349–362, 1929), "properly enters every field of biological inquiry whether the study concerns morphology, life history, physiology, ecology, pathology, genetics, or evolution." To become a parasitologist the student should be first of all a fundamentally well trained biologist. Beyond that his training will vary according to the demands of the special field which he chooses to enter. To expect to achieve appropriate training in this field in less time than is required for any of the learned professions is asking too much.

The field of insect parasitology offers much of value to the solution of major problems, particularly in agriculture and medicine, perhaps we ought to say in the realms of human welfare in general. Will we find

men and women properly trained and capable to step into the front-line trenches and in the various supporting positions in our warfare against these arthropod hosts,—these indomitable, omnipresent, fecund creatures of the chitinous armor? The challenge will not fall upon deaf ears.

MR. F. C. BISHOPP: This is a very well prepared paper and a very hard one to discuss. I think we all agree that it is a most admirable one and splendidly presented. I wish to say this word of appreciation for the fine review of the subject.

PRESIDENT J. S. HOUSER: The next paper is by W. C. O'Kane.

## SOME PROBLEMS AND DEVELOPMENT IN CONTROL OF INSECTS BY CHEMICALS

By W. C. O'KANE, *Durham, N. H.*

ABSTRACT

Many materials used today in sprays were suggested or used thirty or more years ago. Some materials have been in use more than a hundred years. In one sense, our great advance in knowledge of measures for control of plant pests has not realized its full potentiality because of the introduction of new pests and the spread of others introduced earlier. For example, out of a recent list of sixty-four outstanding pests only twenty-four are recognized as yielding to really satisfactory control. In other words, 60% of this list are in an unsatisfactory state as regards control measures.

Nevertheless, although various materials now in use were known fifty years ago, the recommendations for use of these materials are much more exact today than they were formerly. A noteworthy advance has been made in accurate knowledge of the performance of various chemicals. A substantial beginning has been made in a fundamental study of insect physiology, as related to the effects of chemicals. Some noteworthy new chemical compounds have been devised, especially among substitutes for the ordinary arsenicals. These include both complex organic substances derived from plants by extraction and other materials developed in chemical laboratories.

Recently, a significant development has taken place which promises to yield new and better spray materials. The extensive research departments of various large chemical industries are now working in cooperation with the entomologist and plant pathologist, to discover new and effective compounds, and to synthesize needed materials. There is reason to hope that before long we shall have some new and more effective materials, especially among contact insecticides, but also among fumigants, stomach poisons and probably attrahents and repellents.

In the preface to the first edition of Lodeman's memorable book "The Spraying of Plants," Dr. B. T. Galloway wrote as follows:

"In looking back over the past ten or twelve years it is difficult to realize the rapid advance made in combating insects and fungi which attack our cultivated plants. It is not going too far to say that the dis-

coveries made within this period have worked almost a revolution in certain lines of agriculture."

These words were written in 1896, thirty-five years ago.

Some of us have expressed recently almost the same thought in reviewing the progress in insect control achieved within the last ten or a dozen years. We have set forth our belief that entomology has now crossed the border line into a new era of efficiency.

Looking back upon the period in which Lodeman wrote his book we may feel that relatively little had been accomplished at that remote time in the history of economic entomology. But let us see if a real start had not been made.

Among chemical materials that we are using today we find that a surprising number had already made a beginning. Paris green had come upon the stage about 1860. Arsenate of lead, still our major standby among stomach poisons, was developed in 1892. The calcium polysulphides that we call lime sulphur were in use in the early 90's. Kerosene had been recommended as an application for scale on orange as early as 1865 and was in considerable use as kerosene emulsion before 1890. Surprisingly, a kerosene extract of pyrethrum, in which 2½ pounds of flowers were extracted by a gallon of kerosene, which was then made into an emulsion, was devised early in the 90's. Carbon bisulphide was recommended for fumigation of stored wheat insects before 1860, and carbon bisulphide emulsion was recommended in 1891. Hydrocyanic acid gas as a fumigant was developed in 1886. An alcoholic extract of pyrethrum, pointedly suggestive of one of our present uses of the active principles of this plant, had been devised before 1895. Nicotine, as a crude extract of tobacco, which was steeped in water in the presence of lime, dates back to 1763. Fish oil, recently given new attention as a material that may be added to arsenical sprays, was proposed for control of certain caterpillars in 1822. In that same year a solution of mercuric chloride, alcohol and water, was recommended for bedbugs. Oils, such as those of petroleum, were proposed as early as 1877. Even the hot water treatment for insects, with recommendations of submersion or spraying at 120° to 130° F for plants in leaf, or at 200° F for dormant plants, dates back 100 years. Elemental sulphur as an application for mildew goes back 110 years.

These materials, described by Lodeman thirty-five years ago, constitute, apparently, a substantial part of our chemical warfare against insects today. Are we right, then, in saying that recent advances and early prospects constitute a noteworthy step in control of insects by chemical means?

I think that we are. But first let us look at another phase of the present situation.

Statistics indicate that in general, in the last twenty or thirty years, production of major crops in the United States per unit, such as per acre, has not materially advanced. For a long time values steadily increased as the price of products advanced. Yields per farm in various areas also showed a substantial gain through alterations in the crops grown. But, in general, yields per production unit have run pretty nearly the same. May it be that the advances in successful control of insects and plant diseases have often been absorbed by extensive attack on the part of various destructive pests and by the introduction and spread of new pests? I think that in part this is the case.

It is interesting to look at the situation from another point of view.

A recent list of especially destructive insect pests numbered 64 species or closely related groups. With the exception of one insect attacking stored grains, one household pest, and one group that includes carriers of certain human diseases, the list is confined to insects attacking plants.

It is possible to rate each of these insects as to the satisfactory or unsatisfactory condition of our known means of control by application of chemicals. Manifestly, no such rating can be absolute, nor beyond well-taken revision. However, within its limitations it is suggestive. In the same way one can rate each pest as to the availability of satisfactory cultural methods of control, such as utilization of farm practices and the like.

On the basis of these two types of control measures the list has been studied and each insect that it includes has been rated as satisfactory, partly satisfactory, or unsatisfactory, as regards control by chemical means; also, in similar way as regards control by cultural methods.

Of the total number of destructive pests, 64 in all, it is found that 17 may be classified as controllable in satisfactory degree by chemical means, 31 as yielding in partly satisfactory degree, and 16 as not yielding at all in any practical way.

Of the 31 rated as semi-satisfactory, not one yields to satisfactory control measures by cultural means. Of the 16 rated as entirely unsatisfactory from a chemical viewpoint, 7 show satisfactory cultural control measures.

Looking at the group of 64 from the viewpoint of control by cultural methods, 7 rate satisfactory, 37 partly satisfactory, and 20 unsatisfactory. Of the 37 listed as semi-satisfactory, 29 have that same rating from the viewpoint of chemical control, while 8 yield blanks in that

direction. Of the 20 for which no satisfactory control measures are known, 17 yield to satisfactory control by chemical means.

Looking again at the whole group of 64, to see what species are in a satisfactory state as regards control either by chemical or by cultural methods, we find that 24 seem to measure up. In other words, 40 out of the 64 are in an unsatisfactory state as regards adequate solution. These 40 constitute 62% of the total list.

It should be noted in passing that many of our highly destructive pests are not included in this list. For example, the group does not take into account such animal parasites as the Texas fever tick, the sheep tick, the ox warble, the screw worm fly; such household pests as the clothes moths, the bedbug, the roaches; such stored product insects as the saw-tooth grain beetle, the bean weevil, the pea weevil, the rice weevil, the Indian meal moth; such insects affecting man as the body lice. The list includes no forest insects at all, except as the gipsy moth may be so rated.

Thus, with 40 out of 64 highly destructive pests still in a state of unsatisfactory control, we may be challenged in expressing the thought that noteworthy advances in the control of pests by chemical means have been made in the last few years.

But again let us see.

In the early 90's many of the recommendations for control of insects by spraying were based on slender, empirical tests. Thus, arsenic had a long record as an element offering in its compounds substances that were toxic to higher animals. Such a compound, it was manifest, might be toxic to insects. An available compound of reasonable price was Paris green. But Paris green was easily adulterated and was apt to involve too much water-soluble arsenic. Satisfactory arsenate of lead might easily be made by the reaction of lead acetate and arsenate of soda. Its possible use thus suggested itself. It could be prepared relatively free of water-soluble arsenic. Therefore it could be applied to many kinds of foliage in rather heavy doses. So it came into use, first with reference to the gipsy moth and later for a great number of mandibulate insects. A similar simple history lay back of the recommendation and use of other materials at that period.

While a surprising number of chemical elements or compounds now in use were known and recommended at that time, it is true also that recommendations were broad and generalized, and that entomology had not developed important refinements such as those recognized today in the use of these same chemicals.

Again, the requirements to be met on the part of the grower and the public have steadily increased. We are no longer content to harvest and market products that show extensive evidence of insect injury. The grower asks for information by means of which he can produce a clean product and the public demands such a product when it goes to purchase.

Again, we have been forced to meet a steadily increasing number of insect problems through extension of the areas in which a given crop is grown, thereby rendering it liable to destructive attack by insects already present, or through the introduction of pests not hitherto present in this country, or through the spread of pests introduced at an earlier date. One need only mention the European corn borer, the oriental fruit moth, the Japanese beetle, the Asiatic beetles, the Mexican bean beetle, the alfalfa weevil, the Mediterranean fruit fly, as striking examples.

In meeting some of these problems and in laying the groundwork for solving others, the entomologist has in fact made striking advance in the last few years and is reaching a position from which further progress is certain to follow. This holds true with reference to each of the several fields of control measures. While this paper is mainly concerned with problems and developments in chemical means of control, it is equally true that in other fields the picture is promising. In biological control, for example, one need only point to such examples as the promising introduction of certain parasites into Hawaii, the introduction of two new Chalcidoids from Australia to reinforce and complete the work of *Cryptolaemus* in control of the citrophilus mealy bug in California, or the rapid extension in the study and use of such a parasite as *Trichogramma minutum*. Whether or not one indulges in fear as to the too popular interest in such a species as *Trichogramma*, one must admit that a new type of progress has been made, which carries still further such important work as that so well exemplified in the Federal gipsy moth measures and in the work of the Japanese beetle laboratory.

In the field of control by chemical means, the extent of new developments on the way or in the making is unquestionable.

In arsenical compounds we know more today by far than we could even guess at a few years ago. The work of Richardson and Haas for example on the comparative toxicity of acid lead arsenate and of Paris green to the Colorado potato beetle opens a new store of knowledge. The notable research by Campbell and his associates on the performance of lead arsenate in the digestive tract extends the field of information in a vital direction. The work of Fleming and Baker in the development

of a soil treatment with lead arsenate is another significant step. The researches of Dearborn on manganese arsenate and the studies of various entomologists in the field of other arsenical compounds extend our useful knowledge.

Along with this goes the development in fluorine compounds. Marcovitch, Stanley and Adams find that barium fluosilicate and cryolite, both natural and synthetic, offer advantages for control of some important insects. Another compound of fluorine, sodium fluoride, solved the problem of roaches and provided a new and effective treatment for lice on poultry. These are materials that played no part in the recommendations of the early 90's.

Paradichlorobenzene met the issue of the peach tree borer, which up to the time of its advent had necessarily to be classed as an unsolved problem.

The work of DeLong, Reid and Darley on the mortality of leaf hoppers which had imbibed minute doses of copper present in plant juices has a significance which cannot yet be fully realized. Any one who would have said a few years ago that an insect could be killed by a chemical element brought into the tissues of the plant itself would have been termed no scientist. But here is the demonstrated fact.

In the search for a substitute for arsenicals McAllister and Van Leeuwen tested a long series of chemical compounds and found more or less interesting promise in sixty-four members of the series. Yet this work, extensive though it was, is only a beginning. Conceivably, one or several of the promising compounds may give a still better account of itself under different conditions. And even the long list studied is only a start.

Nicotine, though long used as an insecticide, has made new advances. Coupled with a suitable contact agent its toxicity has been stepped up. Coupled with oil a combination has resulted that is important in helping to solve the problem of the codling moth. The undiluted nicotine has been found to help in control of poultry lice when simply painted on the roosts.

Interesting, also, is the recent work of Headlee and Ginsburg with nicotine tannate as a substitute for lead arsenate in late season applications for codling moth.

Study of the chemical structure of nicotine, and research in synthesizing its counterpart, especially the work of Smith, Richardson, and Shepard, has given us the complex beta pyridyl alpha piperidine, conveniently termed neonicotine.

Although pyrethrum has been marketed in a commercial way for more than a hundred years, it has only recently found itself. Today the imports of the flowers approximate ten million pounds a year. Although a kerosene extract of pyrethrum was mentioned in publications as early as 1896, it has remained for the last few years to witness the development of such an extract to the point where whole factories are producing it for use in control of some household insects. As a counterpart, alcohol or acetone extracts are helping to solve the problem of certain insects on plants.

In 1919 McIndoo, Sievers and Abbott were studying the performance of derris. Their work was followed by that of Bishopp and Laake, of Tattersfield and his associates, of deOng and White, of Davidson, and of Shepard. With this was linked a similar study of cubé. Thus, although the bibliography of this group of plants runs back nearly two hundred years, it has been only within the last few years that important scientific data have been worked out. Out of this has come rotenone, which we now know is present in various species of the genus *Lonchocarpus* and the genus *Deguelia*. Very soon supplies of the alkaloid itself in commercial quantity will be available. Here we have a substance which, in a suitable medium, is toxic to various insects in concentrations of 1 to 50,000. Recently, from parts of Europe and Asia comes still another plant extract, anabasin, offering further possibilities.

In the southwestern part of the United States Little has been studying a representative of the genus *Cracca*, which is widely distributed in various states and which, apparently, yields a toxic principle that compares favorably with that derived from cubé or derris. In the southwest they call this plant the Devil's Shoestring. Apparently, no one hitherto had given it attention as a source of a toxic substance available for killing insects.

Lodeman, in 1896, mentioned oil emulsions, but had little to say about anything except kerosene emulsion. This last summer it is estimated that more than five million gallons of so-called white oil or summer oil were used on the Pacific coast alone in spray materials.

In the application of petroleum oils to plants the entomologist enters a field in which the chemistry is complex and in which the expert knowledge possessed by the oil chemist and that offered by the insect physiologist may well be correlated. The relation of various specifications of an oil to its toxic effects on insects requires both expert knowledge and thoro experimentation. These factors include such important matters as the extent and nature of unsulfonatable residues, viscosity, boiling point, and the very process itself used in refining. The question of the effect of

sunshine on the oil plays a part, probably because of ultra violet rays. Oil sprays, both those adapted for winter use and those applicable to plants in foliage, are playing a new and important part in control of many important insects. That they will continue to be a material factor is probably beyond question.

In connection with this development Flint finds that an oil emulsion at a dilution of 1 to 10 has reduced attack by certain stored grain insects from an infestation of more than 99% in the check grain to an infestation of one-half of one per cent in the treated grain.

The present extensive use of oils in connection with codling moth control on the Pacific coast, and the new and less extensive though significant use east of the Rockies, indicates the rapid development now under way in this type of material.

In this connection, perhaps there could be no better illustration of the precision and detail of modern spray schedules, as compared with those of the 90's, than is afforded by the present codling moth schedules in the northwest as contrasted with the recommendations for codling moth control a decade or two ago Not many years have elapsed since we spoke of the codling moth problem as one that could readily be met by an application of lead arsenate at the time of the petal fall, followed perhaps by one or two subsequent applications of the same material. Now we find a schedule that starts with an application of lead arsenate combined with a small amount of fish oil as an adhesive, proceeds through further sprays in which reduced amounts of lead arsenate are combined with summer oils, and follows these in turn with further applications in which summer oils are combined with nicotine. The contrast between the two systems is striking.

The field of attrahents has witnessed rapid expansion in recent years. Thus, the old empirical formulae for grasshopper baits have given way to new and more exact methods using synthetic materials to make the baits effective. Yetter and Steiner in their work in Indiana and in Georgia have explored the performance of many synthetic compounds as an attrahent for the oriental fruit moth. Yothers and various other workers have added much to our knowledge of the right way to use codling moth bait pans. Eyer and Rhodes in New Mexico have investigated the chemical status of fermented baits and are giving us fundamental facts on which to base further intelligent progress. In such research as that relating to the Japanese beetle and the European corn borer, attrahents have acquired a new and important value as a means of discovering new centers of infestation of an introduced insect.

In the field of repellents a new page is turned through the work of

Moore and others in systematic, orderly exploration of groups of chemicals selected and studied on the basis of their structure and relationships, instead of relying on the odors perceived by the human nose.

Workers in the control of insects by fumigation have entered upon a new expansion of research. Vacuum fumigation has solved the problem of safe-guarding various classes of imported merchandise which otherwise must steadily involve further risk of introducing new and serious pests. New chemical measures, such as the use of ethylene oxide, have become available, through the work of Cotton, Rohwer, Back, Ellington and others.

A significant phase of fumigation methods is illustrated in the studies of comparative initial dosages as rendering insects more susceptible or less susceptible to a lethal gas. Following the work of Cotton and his associates on the effects of increased percentages of carbon dioxide on insect respiration, a new line of research is just started which aims to precondition insects, so that they may be rendered specifically more susceptible to available gases.

Since the effective use of contact insecticides involves the question of the contact performance of a given medium, its ability to spread over the integument of an insect, to enter the spiracles and advance in the trachael tubes, and to reach vital cells through other channels, it is important to know something of the physical and chemical factors that bring about effective performance. This line of research is now actively under way, both in England and in the United States, and is yielding data that must certainly be of assistance in further improvement of spray materials.

A large percentage of spray applications are made to plants in leaf. This involves, and always has involved, the problem of spray injury to foliage. Here again progress has been made in arriving at some knowledge of the various conditions that enter into spray injury. The subject is one of great complexity and much time must elapse before adequate information can be available. But a systematic start has been made, and we are beginning to understand that such factors as the pH of plant tissues, the formation of organic acids on the surface of leaves, and the complex reactions that may take place through the interaction of sunlight, moisture and the gases of the air, must be understood in order that intelligent effort may be made in the direction of sprays that are safe to foliage.

Thus, we find the development and use of chemical applications for the control of insects in the midst of new and significant complexity, but also in the midst of new and significant progress. We have acquired

a better understanding of the extent of the field of knowledge that we need to cover; and that alone is a vital beginning.

The directions in which development is taking place and must take place are various.

First of all we need all of the information that we can acquire about insect physiology: about the nature of the digestive activities in each of the important groups of insects, the chemistry of the digestive tract, the nature, the mechanics and the chemistry of respiration;—these especially, but along with these many other important details in the life processes of insects. A good beginning has been made. But we need the productive activities of many more men. There is reason to hope and believe that we are fairly started on this important program.

Because of the importance of stomach poisons in the control of many destructive pests, we need further resourceful and comprehensive research in the improvement of such poisons. In the field of arsenicals alone such studies as those of Campbell and his associates, of Richardson, and others, in the reactions that are taking place when an arsenical such as lead arsenate is ingested, point the way surely toward more effective and intelligent use of arsenical compounds.

The study of plant poisons now available leads to the more effective and intelligent use of these materials as lethal substances for insects. Already so much has been accomplished, and interest is so widespread, that further progress in the near future seems certain.

In the realm of contact insecticides we need not only a broad background of fundamental information on which to build an accurately effective material, but we should have an extensive and well-organized exploration of available chemical substances which, when combined with a suitable medium, may serve as better lethal agents. Here there is opportunity for a significant linkage of the work of the entomologist with that of the specialist in the various fields of chemistry, including the experienced and resourceful chemists attached to the research laboratories of large industrial organizations. The start of such a linkage has now been accomplished through the work of the Crop Protection Institute. New synthetic compounds are under study, representing various fields of chemistry, and some of these are already yielding data that promise well for the future of new and better spray materials.

We need much fuller knowledge of the fundamentals on which to base effective fumigation, and we have made a start in that direction. Hitherto the treatment of insects by lethal gases has been assumed to take place in the normal atmosphere. There is reason to expect that by alteration of the percentage of gases that make up the air, or by intro-

duction of one or more additional gases, perhaps in small amounts, we shall be able to kill insects more effectively, even with the lethal gases now in use.

We need a great deal more information about the nature of the insect egg and its protective covering. Peterson and others have given us the start of this information. It must be greatly enlarged and it must be linked up with the knowledge possessed by the expert chemist, in order that we may build effective ovicides.

We need all of the work that has been done and can be done on the habits of insects. Here there are many workers contributing to the extent of our knowledge. Their efforts are bearing fruit and are certain to continue to do so.

In order to apply chemicals safely to plants in leaf we need to push forward our fundamental knowledge of the relation of chemical applications to the structure and physiology of plant foliage. This should be accomplished by the joint efforts of the plant physiologist and the chemist, with the collaboration of the entomologist. It is well started and will certainly go forward.

It is never safe to offer a prophesy and I do not wish to appear to predict what may be available in the chemical control of insects a few years hence. But I am willing to offer a vision of what might be, perhaps will be.

In such a vision I find us applying as sprays a stomach poison that is attractive to the insect, that is accurately and promptly toxic within its digestive tract, that offers no danger of injury to plants, and that leaves no residues that might be considered harmful to persons or to other consumers of the plant or its products.

I find us applying an improved contact insecticide representing a suitable medium of the correct physical and chemical properties, which carries with it a highly toxic, perhaps a synthetic, compound that promptly produces a lethal effect on nerve ganglia; and I find this material available for insects now considered resistant to contact insecticides, and for any insect regardless of the nature of its mouthparts. I am inclined to find this toxic medium applied in many cases without the addition of water, with resultant material advantages in speed and cheapness of application and in extension to crops not now considered within the realm of practical spray applications.

I find fumigation preceded by a preconditioning of the insects involved.

I find new ovicides available that accurately and effectively are adapted to accomplish that purpose.

With this I find equal progress achieved by the capable and resourceful workers in biological control; and I find continued progress on the part of a thorough quarantine and inspection service, preventing the entry of new pests, limiting the spread of old, and even eradicating some that are already established.

And thus I find the entomologist meeting the challenge of the insect menace.

## Papers on Insect Toxicology and Physiology

*Wednesday afternoon, December 31*

The meeting was called to order by Prof. W. C. O'Kane.

Professor O'Kane asked, since there was no secretary at this session, that Mr. J. G. Conklin make notes on the meeting.

The first paper was presented by Miss Griswold.

## FUMIGATION OF THE IMMATURE STAGES OF CLOTHES MOTHS AND CARPET BEETLES WITH A MIXTURE OF ETHYLENE DICHLORIDE AND CARBON TETRACHLORIDE

By GLENN W. HERRICK and GRACE H. GRISWOLD, *Cornell University*

ABSTRACT

A mixture composed of three parts by volume of ethylene dichloride to one part by volume of carbon tetrachloride is a practical household fumigant for clothes moths and carpet beetles. When confined for 48 hours in an ordinary trunk, two fluid ounces to 5 cubic feet, proved toxic to eggs and larvae of the common clothes moth, and to larvae of both the black and the varied carpet beetle, even at temperatures somewhat below 70°F. Satisfactory results were also obtained when the mixture was used in a tight closet.

In an effort to find a safe, convenient and reliable fumigant for the control of insects attacking clothing and similar household fabrics, the authors have been testing the new mixture recently brought to notice by Cotton and Roark. These authors, in a paper written in 1927[1], speak of this mixture as follows: "A new fumigant consisting of 3 parts by volume of ethylene dichloride and 1 part by volume of carbon tetrachloride is very effective against stored product pests. It is cheap, non-inflammable, non-explosive, non-injurious to stored commodities and is

[1]Cotton, R. T. and Roark, R. C. Journal Economic Entomology, Vol. 20, No. 4, p. 636, 1927.

not dangerous to human life. It is about five times as toxic as carbon tetrachloride." They also reported in this paper the brief results of some fumigation tests with the new mixture against *Anthrenus vorax*, *Attagenus piceus*, and *Tineola bisselliella*[2]. The results were very encouraging.

The experiments discussed in the present paper have now been running through a period of something over a year. The tests have been made with the eggs and the larvae of the common clothes moth, *Tineola bisselliella*, the larvae of the black carpet beetle, *Attagenus piceus*, and the larvae of the varied carpet beetle, *Anthrenus verbasci*. In all, over 900 larvae of these insects and over 300 eggs of the clothes moth have been used in the tests. A picture of the temperature in each case has been obtained by a thermograph, checked up in each instance, by a maximum and minimum thermometer. In many of the experiments, the trunk was placed in a constant temperature room where the temperature did not vary more than one or two degrees during the period of exposure. In other instances, the tests were made under ordinary room conditions, where the temperature varied in a natural way through several degrees during the period of the experiment.

TYPES OF LARVAL CAGES. In all of the experiments the larvae were confined in cylindrical pasteboard cartons, 3¼ inches in diameter and 1⅝ inches in depth. Circular openings, 2 inches in diameter, were cut in the tops and the bottoms of the cartons and, in addition, rows of small holes were punched around the sides. Pieces of fine cheese cloth were pasted securely over all of the openings. In order to make conditions normal for the insects, squares of flannel were placed in the cages. To prevent overcrowding, only five larvae were put in each container. This type of cage has proved very satisfactory for confining larvae during fumigation experiments.

TYPES OF FUMIGATION CHAMBERS. Most of the tests were conducted in an ordinary flat-topped, box trunk. It is an old one, yet is tight and in good repair. It contains just about 5 cubic feet. The trunk was filled with clothes during each of the experiments.

A few of the tests were carried out in an upright closet. This closet is constructed of wall-board and is 4 feet wide, 2 feet deep, and 6¼ feet high, thus containing exactly 50 cubic feet. It has received two coats of paint inside and, in addition, has had all seams closed with a crack filler. This closet represents, in general, the type found in the average dwelling house. In two of the tests no effort was made to seal the openings about the door. In the remaining four experiments, however,

[2]Hummel, in the original description of this insect, spelled the specific name with two s's.

these openings were all sealed with strips of gummed paper, thus making a nearly gas-proof chamber. During the experiments no clothing hung in the closet.

TABLE 1. EFFECT OF ETHYLENE DICHLORIDE (75%) AND CARBON TETRACHLORIDE (25%) ON LARVAE OF THE WEBBING CLOTHES MOTH WHEN CONFINED IN A TRUNK CONTAINING 5 CUBIC FEET

| Date | Amount used in fluid oz. | Time exposed in hrs. | Temp. (F.) | Number larvae used | Results* Dead | Results* Not dead | Checks* Dead | Checks* Alive |
|---|---|---|---|---|---|---|---|---|
| 1930 Oct. 18 | 1 | 48 | 66°–74° | 15 | 10 | 3-f<br>1-a<br>1-m | 0 | 5 |
| Oct. 28 1931 | 2 | 48 | 64°–75° | 10 | 10 | 0 | – | – |
| Jan. 9 | 2 | 48 | 64°–69° | 10 | 9 | 1-f | 0 | 5 |
| Jan. 13 | 3 | 48 | 61°–67° | 15 | 15 | 0 | 0 | 5 |
| Jan. 19 | 3 | 24 | 66°–69° | 15 | 15 | 0 | 0 | 5 |
| Jan. 29 | 2½ | 48 | 59°–67° | 15 | 15 | 0 | 0 | 5 |
| Feb. 24 | 2½ | 48 | 68°–70° | 30 | 30 | 0 | 1 | 8<br>1-m |
| Mar. 3 | 1 | 48 | 78°–80° | 25 | 25 | 0 | 1 | 8<br>1-m |
| Mar. 10 | 2 | 24 | 77°–79° | 30 | 30 | 0 | 0 | 10 |
| Apr. 1 | 2 | 48 | 70°–73° | 25 | 25 | 0 | 0 | 9<br>1-m |
| Apr. 8 | 1 | 48 | 72°–80° | 25 | 4 | 2-f<br>19-a | 1 | 9 |
| June 27 | 2½ | 48 | 70° | 20 | 20 | 0 | 0 | 10 |
| July 8 | 1½ | 48 | 72°–73° | 20 | 20 | 0 | 1 | 8<br>1-m |
| July 14 | 2 | 24 | 71°–73° | 20 | 20 | 0 | 1 | 4 |
| July 22 | 1 | 48 | 73°–74° | 20 | 19 | 1-a | 1† | 4 |

*a, active; f, feebly alive; m, missing.
†Killed by a parasite.

EXPLANATION OF THE TABLES. The results of the fumigations can best be given by organizing the matter in tabular form. The following five tables include the experimental data in a brief, concise manner and need little explanation. The larvae were always placed in the cages the day preceding the experiment, and in some instances, several days in advance. It was thought that possibly the larvae, when well established, might be more resistant to the effects of the gas. When the fumigation experiments were made in the trunk, the cages containing the larvae were packed among the garments with which the trunk was filled. The fumigant was poured into a shallow dish placed on top of the garments. Although the cages containing the larvae were removed from the fumigation chamber at the end of 24 or 48 hours, they were not opened until a week later. It was considered desirable to postpone the examination in order to give any insects which had not been killed, ample time to recover from the effects of the gas.

The data given in Table 1 seem clear and need little explanation. It is evident that one fluid ounce of this fumigant to 5 cubic feet is not sufficient to kill the larvae of the webbing clothes moth (*Tineola bisselliella*). On the other hand, two fluid ounces to 5 cubic feet seems to be sufficient to insure the death of these insects. It is true that, in one experiment where the temperature ranged from 64° to 69°, one larva was found to be feebly alive when the examination was made. It might, therefore, be better to use slightly more of the fumigant when the temperature is below 70° F.

TABLE 2. EFFECT OF ETHYLENE DICHLORIDE (75%) AND CARBON TETRACHLORIDE (25%) ON LARVAE OF THE WEBBING CLOTHES MOTH WHEN CONFINED IN A CLOSET CONTAINING 50 CUBIC FEET

| Date 1931 | Type of closet | Amount used in pints | Time exposed in hrs. | Temp. (F.) | Number larvae used | Results* Dead | Results* Not dead | Checks* Dead | Checks* Alive |
|---|---|---|---|---|---|---|---|---|---|
| Mar. 19 | not sealed | 1 | 48 | 75°–78° | 15 | 11 | 2-f<br>1-a<br>1-m | 0 | 4<br>1-m |
| Apr. 11 | not sealed | 1½ | 48 | 77°–80° | 20 | 19 | 1-f | 0 | 5 |
| Mar. 10 | sealed | 1 | 48 | 72° | 15 | 15 | 0 | 1 | 4 |
| Apr. 1 | sealed | 1 | 48 | 76°–78° | 15 | 15 | 0 | 0 | 4<br>1-m |
| Dec. 1 | sealed | ¾ | 48 | 75°–78° | 20 | 20 | 0 | 1 | 9 |
| Dec. 5 | sealed | ½ | 48 | 76°–78° | 25 | 25 | 0 | 1 | 9 |

*a, active; f, feebly alive; m, missing.

The experiments outlined in Table 2 were conducted in a closet. The fumigant was poured into a large, shallow pan placed on an upper shelf. The cartons containing the larvae were suspended at varying distances below this shelf. No garments were present in the closet during any of the experiments. As indicated in the table, better results were obtained when all cracks about the closet door were carefully sealed. A strong odor was noticeable when the door was opened at the end of each experiment, showing that the gas had been well confined.

In Table 3 are given data on the toxic effect of the ethylene dichloride-carbon tetrachloride mixture on eggs of the webbing clothes moth. The eggs were laid by individual females, each confined in a separate vial. Eggs laid by a moth on one day were used in the fumigation experiments, while eggs laid by the same moth on the following day were retained as checks. Wherever eggs, kept as checks, failed to hatch, it was assumed that they were not fertile. Therefore, no eggs laid by a female, whose eggs failed to hatch in the check, were considered in any of the experiments. If the eggs of a moth in the check hatched, it seems fair to assume that the fumigated eggs, laid by the same female, were also fertile.

TABLE 3. EFFECT OF ETHYLENE DICHLORIDE (75%) AND CARBON TETRACHLORIDE (25%) ON EGGS OF THE WEBBING CLOTHES MOTH WHEN CONFINED IN A TRUNK CONTAINING 5 CUBIC FEET

| Date 1931 | Amount used in fluid oz. | Time exposed in hrs. | Temp. (F.) | Number eggs used | Results* Hatched | Not hatched | Fertility |
|---|---|---|---|---|---|---|---|
| Mar. 10.... | 2 | 24 | 77°–79° | 61 | 0 | 61 | Fertile |
| Apr. 1..... | 2 | 48 | 70°–73° | 43 | 0 | 43 | Fertile |
| Apr. 8..... | 1 | 48 | 72°–80° | 37 | 30 | 7 | Fertile |
| June 18.... | 2½ | 48 | 68°–69° | 71 | 0 | 71 | Fertile |
| June 27.... | 2½ | 48 | 70° | 53 | 0 | 51 2-m | Fertile |
| July 22.... | 1 | 48 | 73°–74° | 43 | 0 | 43 | Fertile |

*m, missing.

Table 4 contains data obtained from experiments conducted with larvae of the black carpet beetle (*Attagenus piceus*). It is evident that two fluid ounces to 5 cubic feet is usually sufficient to kill these larvae. In two instances where two fluid ounces were used, a single larva was found to be feebly alive. These two larvae were kept for further observation and both died a few days later.

TABLE 4. EFFECT OF ETHYLENE DICHLORIDE (75%) AND CARBON TETRACHLORIDE (25%) ON LARVAE OF THE BLACK CARPET BEETLE WHEN CONFINED IN A TRUNK CONTAINING 5 CUBIC FEET

| Date | Amount used in fluid oz. | Time exposed in hrs. | Temp. (F.) | Number larvae used | Results* Dead | Not dead | Checks* Dead | Alive |
|---|---|---|---|---|---|---|---|---|
| 1930 | | | | | | | | |
| Oct. 18... | 1 | 48 | 66°–74° | 5 | 3 | 2-a | – | – |
| 1931 | | | | | | | | |
| Jan. 9.... | 2 | 48 | 64°–69° | 5 | 5 | 0 | 0 | 5 |
| Feb. 24... | 2½ | 48 | 68°–70° | 5 | 5 | 0 | 0 | 5 |
| Mar. 10... | 2 | 24 | 77°–79° | 5 | 5 | 0 | 1 | 4 |
| Apr. 1.... | 2 | 48 | 70°–73° | 5 | 5 | 0 | 0 | 5 |
| Apr. 8.... | 1 | 48 | 72°–80° | 5 | 3 | 2-a | 0 | 5 |
| June 27... | 2½ | 48 | 70° | 15 | 15 | 0 | 0 | 5 |
| July 8.... | 1½ | 48 | 72°–73° | 20 | 20 | 0 | 0 | 5 |
| July 14... | 2 | 24 | 71°–73° | 20 | 20 | 0 | 0 | 5 |
| July 22... | 1 | 48 | 73°–74° | 15 | 15 | 0 | 0 | 5 |
| Oct. 14... | 2 | 48 | 76°–78° | 25 | 25 | 0 | 0 | 10 |
| Nov. 2.... | 2 | 48 | 67°–68° | 30 | 29 | 1-f | 0 | 10 |
| Nov. 12... | 2 | 48 | 68°–70° | 20 | 19 | 1-f | 0 | 10 |
| Nov. 28... | 3 | 48 | 64°–65° | 15 | 15 | 0 | 0 | 10 |

*a, active; f, feebly alive, died a few days later.

In Table 5 are given some data on the effect of the ethylene dichloride-carbon tetrachloride mixture on larvae of the varied carpet beetle (*Anthrenus verbasci*). Since the number of specimens available was somewhat limited, it was only possible to conduct a few experiments with this species. Where larvae were found to be feebly alive at the end of an experiment, they were kept for further observation. In every instance the feeble larvae failed to recover and died a few days later. On the

other hand, the check larvae remained alive and active. It is hoped to secure more material later and thus be able to conduct further experiments with this carpet beetle.

TABLE 5. EFFECT OF ETHYLENE DICHLORIDE (75%) AND CARBON TETRACHLORIDE (25%) ON LARVAE OF THE VARIED CARPET BEETLE WHEN CONFINED IN A TRUNK CONTAINING 5 CUBIC FEET

| Date 1931 | Amount used in fluid oz. | Time exposed in hrs. | Temp. (F.) | Number larvae used | Results* Dead | Results* Not dead | Checks* Dead | Checks* Alive |
|---|---|---|---|---|---|---|---|---|
| Oct. 14... | 2 | 48 | 76°–78° | 15 | 15 | 0 | 0 | 5 |
| Nov. 2.... | 2 | 48 | 67°–68° | 25 | 19 | 6-f | 0 | 10 |
| Nov. 12... | 2 | 48 | 68°–70° | 20 | 17 | 3-f | 0 | 10 |
| Nov. 28... | 3 | 48 | 64°–65° | 15 | 14 | 1-f | 0 | 10 |

*f, feebly alive, died a few days later.

CONCLUSIONS. The experiments outlined above clearly indicate that fumes of the ethylene dichloride-carbon tetrachloride mixture are toxic to both eggs and larvae of the webbing clothes moth and to larvae of both the black and the varied carpet beetle. When two fluid ounces were used in a trunk containing 5 cubic feet, the larvae of all three species were killed even at temperatures somewhat below 70° F. Larvae of the webbing clothes moth were also killed by this fumigant when confined in a tight closet, though at temperatures somewhat above 70° F.

It is hoped that the mixture will soon be available in convenient commercial packages at a reasonable price. The liquid is clean, has a pleasant odor, will keep indefinitely in a tight container and promises to be a suitable household fumigant. Since this material is non-inflammable and non-poisonous to human beings, it should be of practical value in controlling clothes moths and carpet beetles.

The next paper was presented by Mr. Lindgren.

## THE INFLUENCE OF HUMIDITY ON THE EFFECTIVENESS OF CERTAIN FUMIGANTS AGAINST THE EGGS AND ADULTS OF *TRIBOLIUM CONFUSUM* DUV.[1]

By DAVID L. LINDGREN and HAROLD H. SHEPARD, *University of Minnesota, St. Paul, Minnesota*

ABSTRACT

Ethylene oxide, carbon disulfide and chloropicrin were investigated with respect to their toxicity to eggs and adults of *Tribolium confusum* Duval. It was found that toxicity to adults is not affected by ordinary variations in relative humidity. On the other hand dry air conditions reduce materially the effect of chloropicrin and carbon

[1]Paper No. 1071 of the Scientific Journal Series of the Minnesota Agricultural Experiment Station.

disulfide on eggs. Under all moisture conditions tested, ethylene oxide was more effective against the eggs of *Tribolium*, whereas carbon disulfide and chloropicrin were more so against the adults. Contrary to the generally accepted view that the egg is a particularly resistant stage, ethylene oxide appears to be nine times as toxic to the eggs as to the adults of *Tribolium*.

During the course of experimental work on the relative toxicity of various fumigants to the different stages of *Tribolium confusum* Duval, considerable variation in results was noticed, especially when chloropicrin was used against the egg stage. Temperature, but not the humidity, had been controlled in all cases. When results of tests under rather moist room conditions that ranged from 50 to 70 per cent relative humidity, were compared with those obtained by drawing air through a drying tube, much of the error was shown to be due to moisture variations.

By controlling humidity in their fumigation experiments some workers have admitted its importance. Neifert and Garrison (1920) maintained constant moisture conditions by passing air through sulfuric acid of the appropriate density to give 40 per cent relative humidity. Strand (1930) conducted his experiments at average room humidity of from 40 to 50 per cent.

Results have been published which indicate that humidity does not affect the toxicity of some fumigants. Bertrand, Brocq-Rousseu and Dassonville (1919) observed, in tests with adults of one of the grain weevils (*Sitophilus* sp.), that atmospheric humidity has no influence on the insecticidal power of chloropicrin. The influence of air dried over calcium chloride and that of air saturated with water vapor was compared by them. Chapman and Johnson (1925) report that "no relationship was found to exist between relative humidity and toxicity," when adult granary weevils (*Sitophilus granaria* L.) were used in experiments with chloropicrin. According to Gersdorff (1930) it was found by Semikoz, Stepanov and Schmidt (1927) that the insecticidal properties of chloropicrin are not affected by humidity within the range of fatal concentrations and exposure.

Experimental Methods. In general, the methods of Strand (1930) were followed. Certain modifications were adopted, especially the use of an improved fumigation flask designed by Dr. Strand. This is an Ehrlenmeyer of 6.2 liters capacity, closed by a ground glass fitting. Two glass tubes provided with stopcocks are welded into the glass stopper. The one through which fumigants are introduced projects a relatively short distance into the flask. The other tube reaches nearly to the bottom, increasing ventilation when the flask is flushed by an air stream.

Adults and eggs of the confused flour beetle, *Tribolium confusum* Duval, were used in these tests. Cultures on whole wheat flour were

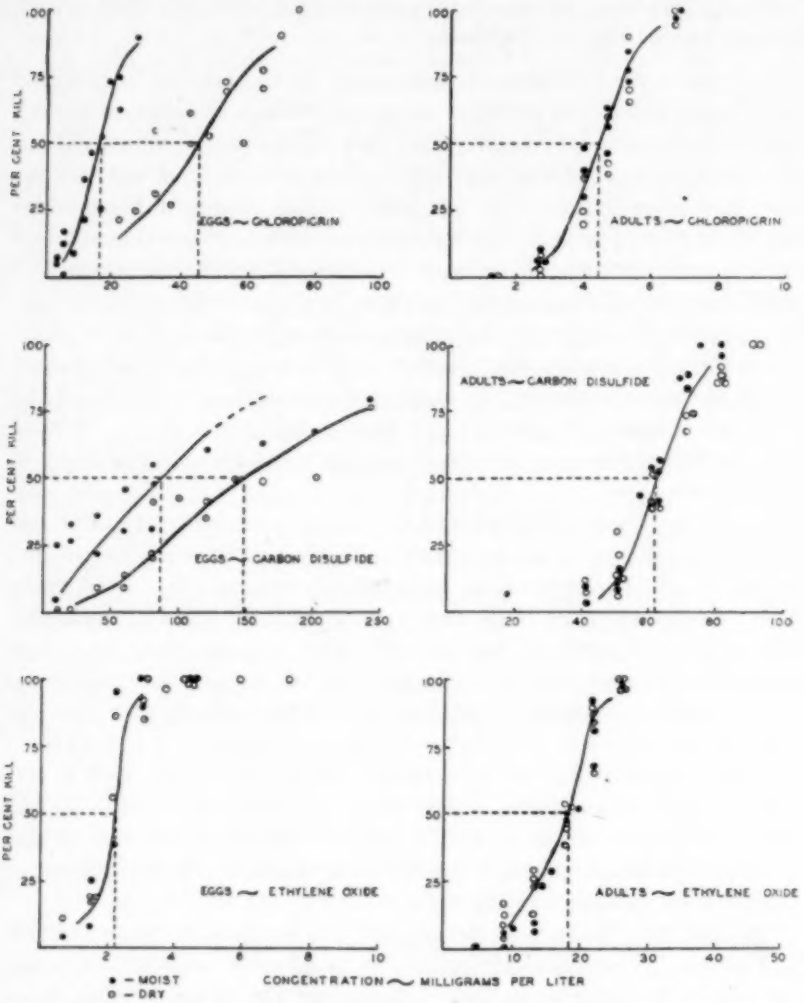



FIG. 13.—Concentration-mortality curves for chloropicrin, carbon disulfide and ethylene oxide used against eggs and adults of *Tribolium*. The effects of dry and moist air conditions are compared.

held at 25° to 27°C. A young culture supplied adult beetles. Eggs laid only by young adults were used. Eggs of *Tribolium* in which embryonic development is rather advanced (5 days old) are more easily killed by

chloropicrin than eggs only one day old. Hence, no eggs older than two days were used in the humidity experiments.

Three fumigants, chloropicrin, ethylene oxide and carbon disulfide, were tested. They were measured volumetrically with pipettes graduated to 0.01 cc. Measurement of ethylene oxide was done in a cold room maintained at —15°C. Its density at that temperature is 0.915. Densities of chloropicrin and carbon disulfide at the temperature of the laboratory (24°C.) are respectively 1.649 and 1.256.

The insects for fumigation, either adult beetles or eggs, were placed in small cylindrical cages made of bolting cloth. From 30 to 35 insects were used in each test. A cage was hung in each flask, a hook being provided for the purpose near the lower end of the longer tube. The pressure in each flask was then reduced by ten centimeters and the fumigant drawn in through the shorter tube by suction. By this method the contents of the flask had the same relative humidity as the room. In dry air experiments a calcium chloride drying tube (16 inches long and one inch in diameter) was attached to one opening, the dried air being drawn through each flask for at least three minutes. It is thought that not over ten per cent humidity, and probably much less than that amount, remained in the air.

The fumigation flasks were held at 25°C. for five hours. In case there might be adsorption of fumigant to the bolting cloth, the treated adult beetles were removed to clean cages where they were kept at 23° to 26°C. for about 36 hours. Checks showed no natural mortality of young adults. Treated eggs were placed in clean vials without flour and kept at 27°C. until hatching was completed in 8 or 9 days. It was necessary to remove larvae as soon as hatched, otherwise unhatched eggs were likely to be devoured. Checks, kept from each batch of eggs used, usually showed a normal hatch of 80 to 85 per cent. Calculation of percentage mortality was by Abbott's formula, $\frac{x - y}{x}(100)$, where $x$ is per cent of hatch in the check and $y$ that in the treated lot.

A number of trials were made at each concentration, each one being represented by a point in the following figures. Experiments were carried out in pairs as much as possible, in each pair one at low and the other at high humidity.

Discussion of Results. From these results it is obvious that considerable humidity variations do not affect the toxicity of chloropicrin, carbon disulfide and ethylene oxide to adults of *Tribolium*. It is equally obvious, however, that any considerable variation in this

factor will influence mortality of eggs fumigated with chloropicrin and carbon disulfide but, apparently, not those treated with ethylene oxide.

TABLE 1. FIVE-HOUR MEDIAN LETHAL CONCENTRATIONS FOR EGGS AND ADULTS OF *Tribolium confusum* DETERMINED FOR LOW AND HIGH RELATIVE HUMIDITIES AT 25°C.

| Fumigant | Eggs | | Adults | |
|---|---|---|---|---|
| | Low humidity mg./liter | High humidity mg./liter | Low humidity mg./liter | High humidity mg./liter |
| Chloropicrin | 45 | 16 | 4.4 | 4.4 |
| Carbon disulfide | 147 | 87 | 63 | 63 |
| Ethylene oxide | 2 | 2 | 18 | 18 |

In the accompanying table are given the median lethal concentrations under low and high humidity conditions for both adults and eggs of *Tribolium*. The eggs under fairly moist conditions are affected by about a third the concentration of chloropicrin required when the eggs are exposed to dry air. Carbon disulfide is somewhat less than twice as toxic when moisture is present. Moisture does not affect toxicity of ethylene oxide to the eggs.

It is a common statement that insect eggs are the most resistant stage. In the case of *Tribolium* the eggs are more resistant to chloropicrin and carbon disulfide than the adults. On the other hand the eggs are killed by only eleven per cent of the concentration of ethylene oxide required to kill adults. One may say, then, that a particular stage of an insect may be relatively resistant to some materials and comparatively susceptible to others.

The agreement between the figures given here for chloropicrin and carbon disulfide and those given by Strand (1930) is gratifying. Median lethal concentrations given by the latter author are respectively 4.70 and 60.85. This relatively small variation in the results secured by different workers indicates that the method involved has much to recommend its use.

## LITERATURE CITED

BERTRAND, G., BROCQ-ROUSSEU and DASSONVILLE. Influence de la temperature et d'autres agents physiques sur le pouvoir insecticide de la chloropicrine. Compt. Rend. Acad. Sci., Paris 169, p. 1059–1061. 1919.

CHAPMAN, R. N., and JOHNSON, A. H. Possibilities and limitations of chloropicrin as a fumigant for cereal products. Jour. Agri. Res. 31 (8), p. 745–760. 1925.

GERSDORFF, W. A. (Supplement to chloropicrin bibliography.) U. S. Dept. Agri. Bur. Chem. and Soils, mimeographed. 1930.

NEIFERT, I. E., and GARRISON, G. L. Experiments on the toxic action of certain gases on insects, seeds, and fungi. U. S. Dept. Agri. Bul. 893, 16 pp. 1920.

SEMIKOZ, F. F., STEPANOV, V. F. and SCHMIDT, B. N. (Laboratory data on the action of chloropicrin, chlorine, and carbon disulphide as disinfectants and experiments to determine their influence on the insect fauna in the burrows of ground squirrels.) Rev. Microbiol. et Epidemiol. 6, p. 41–68 and 128–130. 1927.

STRAND, A. L. Measuring the toxicity of fumigants. Ind. and Eng. Chem., Analyt. edit., 2, p. 4–8. 1930.

Mr. W. E. Hinds announced that the papers on insect physiology would be presented after the reading of the papers on insect toxicology at this session.

## TOXICITY STUDIES BY HYPODERMIC INJECTION OF *CELERIO LINEATA* LARVAE

By GEORGE HOCKENYOS, *University of Illinois* and JOHN LILLY, *University of Wisconsin*

ABSTRACT

In the comparative study of the toxicity of insecticides it sometimes seems advantageous to inject their solution directly into the insect body and thus eliminate the extra factor of absorption. A technique for this procedure is given for use on large larvae. A satisfactory end point of paralyzation of the neuro-muscular activity is also established.

Data is presented graphically which indicates that for both organic and inorganic materials there often appears to be an optimum point of dilution at which it can be most efficiently used. Some possible reasons for this are suggested. This method also appears to have possibilities for such physiological studies as the working of the nervous system and the absorption of materials by tissue cells.

There are three possible ways for a toxic material to enter the insect body. It may be absorbed through the wall of the alimentary canal; it may be absorbed through the respiratory system; or it may in some cases be absorbed through the body wall itself.

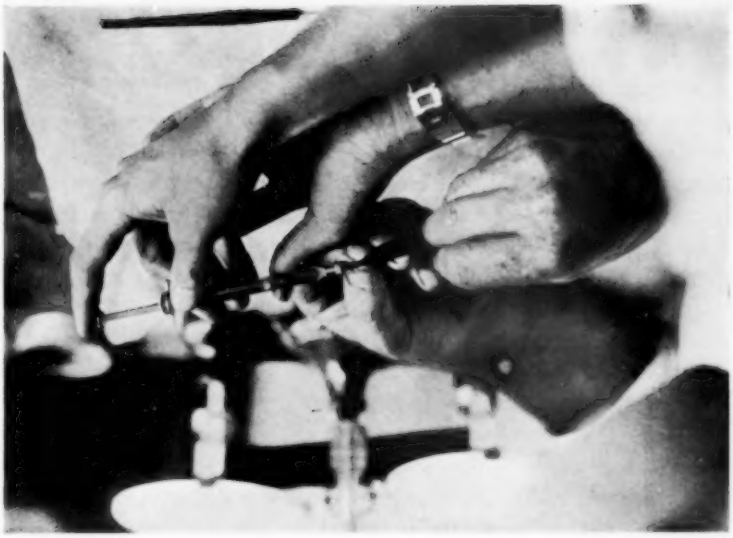
Entomological literature is replete with studies of the concentrations required and the influence of physical factors in the killing of insects with contact poisons. Such studies give little indication of the actual amount of toxic material required to kill the insect. Some quantitative data is available on the absorption of stomach poisons, notably the work of Campbell (3, 4, 5). The second method is extremely difficult to study quantitatively and is affected by many factors. Little is known about the third method of entrance because it is difficult to separate it from the second, but scattered evidence indicates that sufficient toxic material may be absorbed through the body wall to cause death. The best general work on these last two methods is that of Shafer in 1911 (8).

In the face of these facts, it would seem highly desirable to determine the actual amount of toxic material required to kill an insect when it is injected directly into the body cavity in known quantities. This method eliminates the extra factor of absorption. Hypodermic injection of insects is not a new idea, but has been tried by several entomologists with various purposes in mind. Shafer (8) used it qualitatively as a histological method of detecting hydrogen sulfide absorption. Crozier (7) studied the effects of the injection of atropine and several other drugs upon muscular activity, but only minor emphasis was laid on nicotine. Campbell (3) developed a delicate technique for the injection of small larvae with solutions of stomach poisons.

PROCEDURE AND TECHNIQUE. For this work, nearly mature larvae of *Celerio lineata*, the Horn Tailed Parsley Caterpillar, were used because of their large size, uniformity and a temporarily abundant supply. Most of the experiments were made with 40% nicotine sulfate (Nicotinum) but several other materials were tried for comparison and supplementary data. A B-D tuberculin hypodermic syringe graduated to 0.01 cc. and equipped with a 27 gauge ¾ inch platinum needle was used to administer the injections. Considerable experimentation was required to find a satisfactory technique for holding the larvae, establishing a location of injection, choosing the volume of solution to be injected and especially in establishing satisfactory end points of results.

The standardized procedure as finally developed consisted of making a puncture in the body wall, slightly to one side of the mid-dorsal line on the second thoracic segment so as not to injure the heart mechanically. A sharp dissecting needle was used for this purpose and the opening was made just large enough for a small drop of blood to ooze out. The hypodermic needle was then inserted at the puncture and its point extended posteriorly into the larva for ½ inch just beneath the body wall. The method of holding is best shown by Plate 8, Fig. 1, where two operators are making the injection. Plate 8, Fig. 2 shows how it is possible for one operator to satisfactorily hold the larva and make the injection. 0.05 cc. was the volume selected for all the injections except those which are otherwise specified. This was used because it was convenient to read on the syringe and did not materially increase the fluid contents of larvae of this size. It was not necessarily the volume at which a given dosage of nicotine was most effective, as is shown later.

Satisfactory biological end points are seldom easy to definitely establish and distinguish. Nicotine injection always acts as a stimulus at first, giving rise to spontaneous writhings and threshings as well as



1. Method of injection when two operators perform the operation.

2. Showing how one operator can satisfactorily hold the larva and perform the injection.

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temporarily heightened sensitivity to stimuli. This definite neuromuscular excitation soon gives way to quietness, if the injection is strong enough to be effective, and usually a definite end point may be observed at which all the body muscles suddenly lose their tonus and the insect's powers of muscle coordination are lost. This is called the "knockout" point and is the most satisfactory of those used in this work. However, it was often desirable to note the condition of the larvae at the end of an hour or at other time intervals after injection. The end points selected for these readings were "practically normal," "unable to crawl," and "completely paralyzed." "Practically normal" meant able to crawl readily, "unable to crawl" indicated that the larvae could right themselves when placed on their backs but lacked the necessary muscle coordination for crawling, and "completely paralyzed" meant that all powers of movement except reflex-like twitchings of appendages had been lost.

The following precautions were found to be necessary in this work. Larvae were not kept over from day to day, but a fresh supply was gathered from the field each morning. Parasitized larvae were avoided. Larvae cannot be kept for very long in dark boxes and must never be piled up in a container as they spew an irritating, viscous, and basic salivary secretion upon being touched and handled. A cone-shape screen cage, about a foot high, bottomless, and with a small door on the side was found to be an excellent container. It was set over an area of floor covered with excelsior and the larvae kept themselves from piling up by crawling up the sides. The excelsior absorbed all excess moisture. When an injection is imperfectly made, it is necessary to discard that specimen and repeat the operation. Campbell (3) cautions against the loss of very much blood. Mechanical injury of the aorta is to be especially avoided. A uniform pressure and speed in making injections is necessary in order to make the rate of diffusion comparable in a series of larvae. Distilled water was used in preparing all of the dilutions. This work was done at room temperatures ranging from 21 to 26°C. As the larvae are most active in the light, the end points were always read where there was plenty of light present.

RESULTS. Fifteen larvae of various weights were injected with cold water in amounts up to 0.10 cc. None of these check larvae showed any injurious effect and remained perfectly normal, except for a temporary slight lessening of activity.

Since the larvae varied in weight from 2.5 grams to 6 grams, it was supposed that the median lethal dose, Trevan (10), should be proportional to the body weight, and this was the assumption followed

by the other workers mentioned. Accordingly a long series of injections of Nicotinum in concentrations varying from 1–5 to 1–1000 were made, giving each larva 0.01 cc. per gram body weight. Thus a four-gram larva received a 0.04 cc. injection. Results showed that while the amount required to paralyze a larva is influenced by its size, they are apparently not directly proportional in an exact ratio, the smaller specimens being relatively more resistant than the larger ones. Thus unless otherwise specified, all these data are taken from larvae weighing between three and four grams each and injected with 0.05 cc. of solution.

Due to the fact that the data was quite voluminous, it was thought best to express it graphically and to state its indications in words instead of numbers. Unless otherwise specified, each point on a graph was established by the arithmetical average result of the injection of 10 larvae. The collective discussion of the findings is given after all the data is presented. These graphs are all dose-effect or toxicity curves in which the effect is plotted as the ordinate against the dosage or dilution as the abscissa.

Fig. 14, I is the only one included which is based on data from larvae injected in proportion to their body weights. Although the points established with dilutions less than 1–20 are far too few to be conclusive, it is indicated that for this set of conditions a dilution of 1–15 is more effective than those both above and below it.

Fig. 14, II was made especially to show the relation between the speed of effectiveness and the distance from the point of injection to the head. Each of these points were established by data from two larvae. The place of injection with 0.05 cc. of a 1–50 dilution of Nicotinum is indicated by the segment number. The points on the dotted line were established by measuring the distance from the head to the middle of each segment in mm. and plotting these distances on the ordinate. It is readily seen that there is a surprisingly direct correlation between the length of time required to bring on the "knockout" point and the distance of the point of injection from the head. (In making these injections the puncture was made dorsally in the segment posterior to the one numbered, so that the injection was actually made into the segment indicated).

Fig. 14, III was made to show the effectiveness of the same amount of Nicotinum when applied in a large volume of low concentration as compared with a small volume of high concentration. For example, 0.0006 cc. of pure Nicotinum was injected in the one case as 0.03 cc. of 1–50 dilution and in the other as 0.06 cc. of 1–100 dilution. Although the

data is limited, it is very consistent in indicating that for injection work under these conditions, the 1–100 dilution is much more efficient than the 1–50.

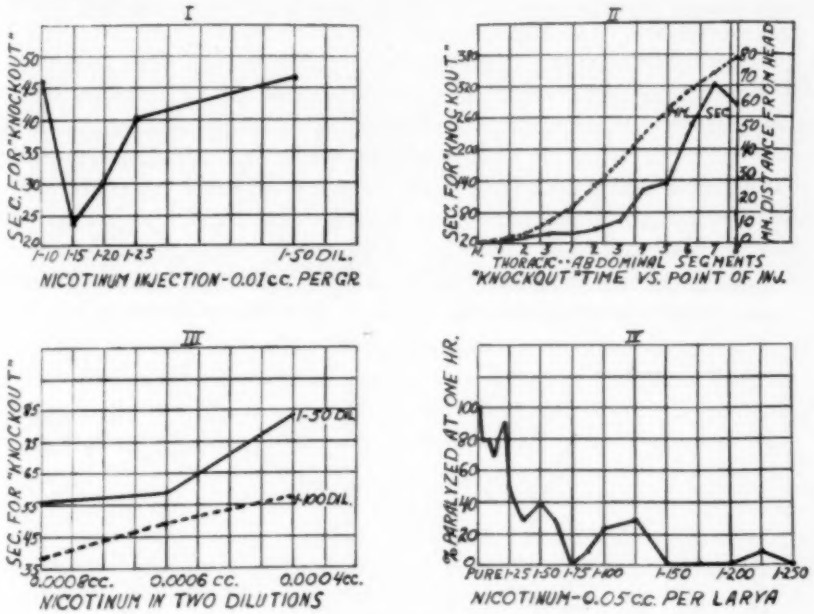



FIG. 14.—Toxicity Results.

Another interesting test not shown graphically was the injection of 10 larvae with a 1–50 dilution of Nicotinum at 12°C. and 10 more at a temperature of 36°C. The average number of seconds for the "knockout" point in the first series was 27.5 while for the other group it was 22.5, showing that at higher temperatures the injection probably is effective a little more quickly. Four series of 10 were made to show the effect of varying the pH but the differences here were slight.

Fig. 14, IV indicates that the toxicity curve for Nicotinum is quite gradual, when the percentage completely paralyzed at the end of one hour is considered. It shows that only pure Nicotinum can be expected to paralyze 100% of the larvae injected with 0.05 cc., while 1–5 to 1–25 may be expected to paralyze over 50%, and dilutions from 1–25 to 1–100 something less than 50%. Dilutions above 1–100 are variable but usually give less than 20% paralyzation. Here again we have a suggestion that 1–100 and 1–125 dilutions are more effective than some of the more concentrated ones.

Fig. 15, V is included to give some comparison of dipping the larvae in the Nicotinum solution. These were smaller larvae and only five of them were used to establish each point. It is not easy to compare dipping with injections because the dipping is not quantitative.

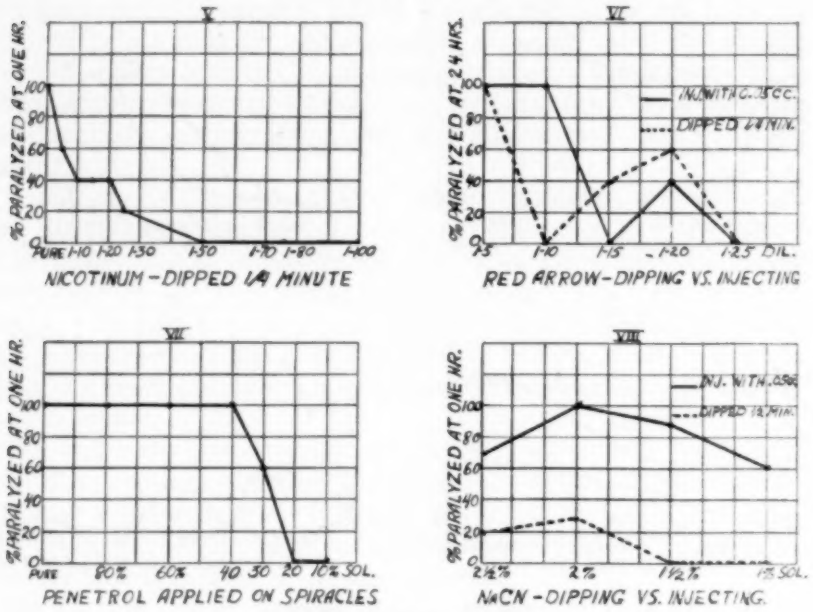



FIG. 15.—Toxicity Results.

Fig. 15, VI is a comparison of dipping and injecting made with another alkaloid preparation, Red Arrow, made by McCormick and Co. of Baltimore, which is a pyrethrum contact insecticide. It appears that at the lowest dilutions the injections are most effective but this may be reversed when higher dilutions are made. As this material is quite viscous, the higher dilutions perhaps facilitated its entrance into the tracheae. This cannot be fairly compared with any of the Nicotinum graphs as these data were taken after 24 hours. Here again there is a strong indication both in the dippings and the injections that there is an optimum dilution which will give the most efficient use of the material. These points were established from the averages of five larvae each.

Fig. 15, VII shows the relative effectiveness of different dilutions of Penetrol, a miscible oil activator and spreader for nicotine, when a tiny droplet of it is placed upon each spiracle. The decisive results shown by the descending concentrations show that for this end point, the

number paralyzed is determined by its dilution, and that the median lethal dose lies between 20 and 40 per cent solutions. It appears that the paralyzation in this case may be largely due to the mechanical plugging of the spiracles. These points were also established by five larvae each.

Fig. 15, VIII shows another comparison of dipping and injecting in which sodium cyanide is the toxic agent. The dipping for one-half minute appears comparatively ineffective. Again there is a suggestion of an optimum dilution of the toxic agent.

Several other toxic materials were used in making injections by way of comparison. Work with sodium arsenite indicated that under these conditions its median lethal dose is a solution less than 2%. 5%, 4% and 3% were no more effective than 2%, possibly because no more of the poison was absorbed by the tissues in the higher concentrations. Copper acetate injections were not effective unless they were made with at least 2% solutions, and then little change was noted in less than 24 hours. Dipping one-fourth minute in kerosene was much more effective than injecting with 0.05 cc. of the same material.

## Discussion and Conclusions

1. The most significant and consistent fact indicated by this study is that there appears to be an optimum point in the dilution of several toxic materials when they are used to destroy insects. As this optimum point of dilution may be much higher than other less effective ones, the efficiency of some insecticides may depend largely upon their concentration. It seems that this indication is at least worthy of further studies.

Probably this is true in the case of alkaloidal salts like nicotine sulfate because there is an optimum dilution for the most efficient hydrolysis. Similarly the ionization constant of some inorganic poisons may be just as important. Crozier (6) found that cell penetration by acids is directly proportional to their ionization constant, but that it is also altered by some other factor which he did not determine. Another possibility is that the osmotic pressure through the cell walls of the absorbing tissue cells is varied by the dilution of insecticide used. Campbell (3) suggested that the lowered proportional efficiency of high concentrations of stomach poisons is due to a smaller proportion of the toxic material being absorbed as compared to the lower concentrations.

2. It appears that it takes a larger quantity of nicotine sulfate to kill an insect when it is injected into the body than it does as a spray. Blumenthal (2) has found that insect bloods may be expected to contain more or less sugar. Baker and De Long (1) have demonstrated that glucose or glycogen exert an antagonistic influence which destroys the

toxic action of sodium cyanide, and suggested that a similar reaction occurs with alkaloids. Shafer (8) also concluded that a contact spray is more effective in vapor form than as a liquid because vapors penetrate and are absorbed much more rapidly.

3. The speed of paralyzation of a larva injected with nicotine sulfate of a given dilution is in direct proportion to the distance from the point of injection to the head. Thus larval muscle coordination is shown to be centered in the brain.

4. The influence of the temperature and the pH of a nicotine sulfate solution upon its effectiveness are probably not as great as might be expected.

5. The results are surprisingly consistent when the fact that a biological process and end point are involved. Trevan (10) strongly emphasizes the difficulty of establishing a median lethal dose of any drug and points out the large variations to be expected when such small numbers are involved.

6. The authors are fully aware of the artificial factors involved in this work, and the dangers of drawing conclusions based on limited data. This is considered as a preliminary investigation and it is hoped that it may pave the way to the securing of more conclusive evidence along the same lines.

## Literature Cited

1. Baker, A. D. and DeLong, W. A. 1927. Glucose as an antagonist. Science 66: 457–458.
2. Blumenthal, R. 1927. A micro blood sugar method and the blood sugars of insects. Science 65: 617–619.
3. Campbell, F. L. 1926. Speed of toxic action of arsenic in the silkworm. Jour. Gen. Phys. 9: 433–443.
4. Campbell, F. L. and Filmer, R. S. 1929. A quantitative method for estimating the relative toxicity of stomach-poison insecticides. Trans. IV. International Cong. Ent. 523–533.
5. Campbell, F. L. 1930. A comparison of four methods for estimating the relative toxicity of stomach poison insecticides. Jour. Econ. Ent. 23: 357–370.
6. Crozier, W. J. 1916. Cell penetration by acids. Jour. Biol. Chem. 24: 255–257.
7. Crozier, W. J. 1922. Reversal of inhibition by atropine in caterpillars. Biol. Bul. (Wood's Hole) 43: 238–243.
8. Shafer, George D. 1911. How contact insecticides kill. Mich. Agr. Col. Tech. Bul. 11, 65 p.
9. Shackell, L. F. 1925. The relation of dosage to effect. Jour. of Pharmacol. and Exp. Therap. 25: 275–288.
10. Trevan, J. W. 1927. The error of determination of toxicity. Roy. Soc. (London) Proc. (B) 101: 485–514.

At the conclusion of this paper Doctor Haseman stated that one of his graduate students was doing similar experimental work on larvae of codling moth. Doctor Hartzell remarked that he, too, was undertaking experiments along this line. One of the members asked why pure nicotine was not more effective when injected into the body of an insect. Doctor Hartzell stated that possibly the presence of glycogen in the body fluid may explain the lack of toxicity of pure nicotine when injected into the body of the insect.

Professor O'Kane asked if the location of the material within the insect's body had been determined after the material had been injected. Mr. Hockenyos replied that it had not.

Professor O'Kane called for the reading of the next paper.

## ADDITIONS TO OUR KNOWLEDGE OF THE TOXICITY OF STOMACH POISONS TO INSECTS

By J. W. BULGER, *Bureau of Entomology, U. S. Department of Agriculture, Takoma Park, Md.*

ABSTRACT

The so-called sandwich method was used to study the effect of calcium hydroxide, calcium caseinate, precipitated sulfur, dry Bordeaux mixture, and hydrated ferric oxide on the toxicity of acid lead arsenate for the fourth instar silkworm. No remarkable effect was produced by any of these substances. It is fairly certain, however, that calcium hydroxide and calcium caseinate increase the toxicity of acid lead arsenate when mixed with it in approximately equal proportions by weight. The indications are that precipitated sulfur may increase the toxicity of acid lead arsenate, and that dry Bordeaux mixture and hydrated ferric oxide may decrease it. Experiments were made by the sandwich method on the relative susceptibility to acid lead arsenate of the following caterpillars in the last instar: Eastern tent caterpillar (*Malacosoma americana* Fab.), fall webworm (*Hyphantria cunea* Drury), walnut caterpillar (*Datana integerrima* G. & R.), and the catalpa sphinx (*Ceratomia catalpae* Boisd.) With the median lethal dose of acid lead arsenate for the fourth-instar silkworm as the standard of comparison, it was found that the first two insects were less susceptible and the last two more susceptible to acid lead arsenate than the fourth-instar silkworm. It was also shown that, although the median lethal doses of acid lead arsenate and cuprous cyanide are different for the catalpa sphinx and silkworm, their relative toxicity is about the same for each of these insects. Certain improvements in the sandwich method are described.

It has been shown by Campbell and Filmer (3) that the relative toxicity of stomach poisons for the silkworm can be determined quantitatively by the so-called sandwich method. This method is also suitable for the quantitative study of certain other aspects of the toxicity of stomach poisons. The present paper deals in a preliminary way with

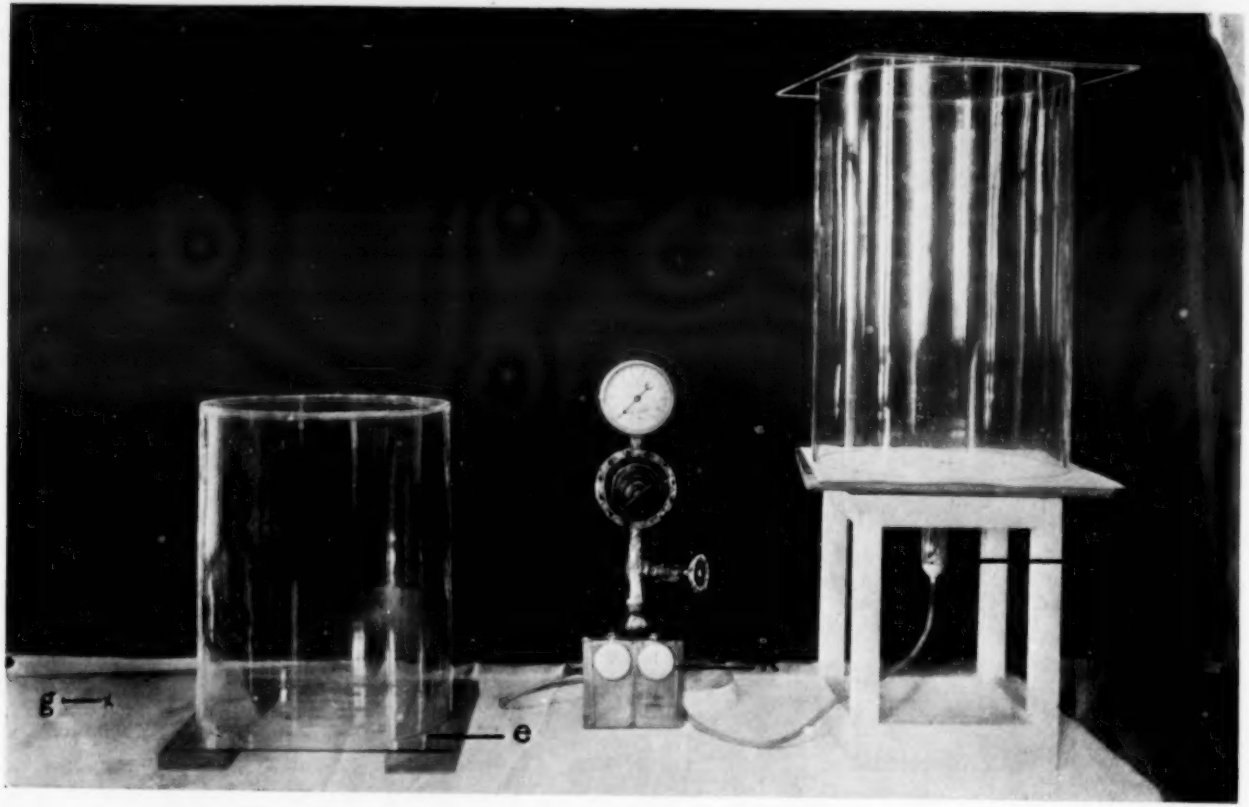
two such problems: (1) the effect of substances commonly applied with acid lead arsenate on its toxicity, and (2) the relative susceptibility of different species of insects to the same poisons. The former project was suggested by Porter and Sazma.[1]

METHODS. The sandwich method used by the writer was essentially the same as that described by Campbell and Filmer (3), but with certain improvements which are described below, designed to control the quantity and distribution of dust and to save time.

In the course of the work at this station with the sandwich method, Campbell found by colorimetric determination of the distribution of a potassium permanganate dust that a gradient in distribution could be detected. The concentration of this dust was always slightly higher on the side of the dusting plate nearest the original position of the bell jar into which the dust was blown. The present writer observed this to be due to the tendency of the dust cloud to roll out of the bell jar upon the leaf disks nearest the jar while it was being lifted and moved over upon the dusting plate on which the leaf disks were placed. The apparatus was accordingly modified by the writer and, incidentally, enlarged. Two glass cylinders (Pl. 9) 12 inches in diameter were employed. The dust was blown into a cylinder (a) 18 inches high, which was closed at both ends by suitable plates (c and d), except for a small hole in the bottom plate through which the dusting pipette (f) was inserted. The second cylinder (b), 15 inches high, stood open next to the dusting cylinder on a glass plate (e) bearing the leaf disks and also the cover glasses used in determining the weight of the various dust deposits. When the larger particles of dust had settled in the dusting cylinder (a), it was lifted and moved to a position 15 to 18 inches above cylinder (b), the plate closing its bottom was then removed, and it was quickly lowered and placed upon cylinder (b). The dust cloud then fell slowly through the cylinders and settled upon the leaf disks and on the cover glasses on the dusting plate at the bottom. When the desired deposit of dust was obtained, the two cylinders were lifted vertically as high as possible above the dusting plate and placed on the table (g) at one side of the dusting plate. Further improvements in this apparatus and procedure are being evolved for use in subsequent experiments.

In order to control more accurately the quantity of dust blown into the cylinder, a reducing valve fitted with a gauge (h) graduated in pounds and

[1]Unpublished laboratory data obtained by these workers indicated that the addition of lime sulfur, hydrated lime, and Bordeaux mixture reduced the effectiveness of lead arsenate in the control of the codling moth.




UNIV. OF MICH.

Apparatus used in dusting leaf disks, (a) Dusting cylinder, (b) Settling cylinder, (c) Cover, (d) Bottom, (e) Dusting plate, (f) Dusting pipette, (g) Table, (h) Gauge, (i) Inlet valve, (j) Outlet valve, (k) Stop watches.

ounces was installed between the compressed-air line and the dusting pipette (f). A valve (i) was placed at the inlet and a valve (j) at the outlet of the reducing valve. With the inlet valve open and the outlet valve closed, the gauge was adjusted to the desired pressure. Then the inlet valve was closed and the outlet valve quickly opened, permitting the air in the reducing valve to pass through the dust in the dusting pipette, which resulted in a puff of air and dust being blown into the cylinder. Stop watches (k) were used to time the period of settling of the larger particles and the period of exposure of the leaf disks to the cloud of fine dust. A few preliminary experiments sufficed to indicate the pressure and settling periods that will lead to such quantity of an insecticide being deposited on the leaf disks that the insects will take about the median lethal dose. Thereafter doses can be so controlled that nearly all are sufficiently close to the median lethal dose to be useful in determining it, with a consequent saving of time and insects.

Time was saved in another part of the procedure by promptly enlarging photographically the partly eaten sandwiches, so that complications in measuring due to unequal shrinkage of the sandwiches in storage were obviated. This photographic work was done in the dark room of the laboratory by the use of a suitable enlarging camera. It was also found that the partially eaten sandwiches can be stored in a refrigerator for a week or more, if necessary, without shrinkage if the taped edges of the plates are dipped in hot paraffin to exclude the air.

It might be mentioned here that Stellwaag (7) recently tested the sandwich method and proposed certain simplifying changes in it. He has termed his procedure the "Campbell-Stellwaag method."

## Experimental Work

The Effect of Substances Added to Acid Lead Arsenate on its Toxicity. The effect of the following substances was studied: Calcium hydroxide, calcium caseinate, precipitated sulfur, dry Bordeaux mixture, and hydrated ferric oxide. The last-mentioned product was one recommended by Ginsburg (4) as a sticker and arsenical corrective. The hydrated ferric oxide was analyzed by the Bureau of Chemistry and Soils with the following results: Insoluble in hydrochloric acid 0.13 per cent; loss on ignition (probably all water), 12.93 per cent; ferrous oxide (FeO) 9.22 per cent; ferric oxide ($Fe_2O_3$) 77.15 per cent. The samples of other substances were not analyzed. The sample of pure acid lead arsenate was the one previously used by Campbell (2). It has since served as a standard of comparison for all work at this station on the toxicity of such stomach poisons.

The data on the toxicity of acid lead arsenate alone for the fourth-instar silkworm were secured from time to time during the months of May, June and July, 1931. The results shown as a mortality curve (A) in Figure 16 are based upon doses taken by 318 insects. This curve is

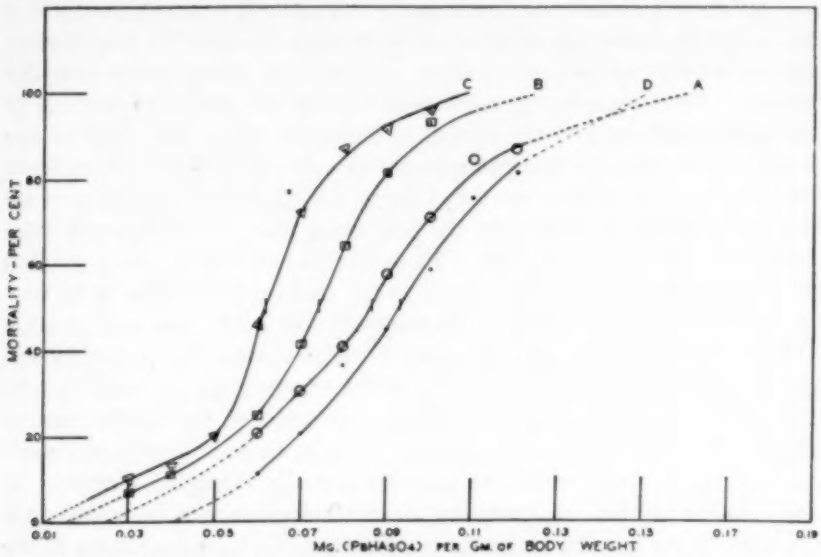



FIG. 16.—Effect of certain substances on the toxicity of acid lead arsenate for the fourth-instar silkworm. Curve A (318 insects), acid lead arsenate; B (80 insects), acid lead arsenate plus calcium hydroxide; C (93 insects), acid lead arsenate plus calcium caseinate; D (57 insects) acid lead arsenate plus hydrated ferric oxide.

similar to the one published by Campbell (2), the median lethal dose at 50 per cent mortality in his curve being 0.09 mg. of acid lead arsenate per gram of body weight and that in the writer's curve 0.086 mg. All curves in the present paper were smoothed by the method of moving averages according to Mills (5).

The tests with acid lead arsenate plus other substances were also made during May, June, and July, 1931, but usually not on the same days on which acid lead arsenate alone was tested. In these tests the leaf disks were first dusted with acid lead arsenate and the quantity deposited per leaf disk was determined as usual by weighing cover glasses. Then the same leaf disks were dusted again with the substance to be added, additional cover glasses that had received both deposits of dusts being weighed to determine by difference the quantity of the substance added. In each weighing three cover glasses were used, one placed in about the center of the dusting plate and one on each side about half way between

the center and the edge of the jar. The average weight of the deposits on the three was taken as the weight of the deposit upon each leaf disk. An effort was made to deposit on the leaf disks equal quantities of acid lead arsenate and the other substance. Mixtures of known composition of the two substances might have been dusted on the leaf disks, but it was thought better to apply them separately because a mixture might not retain its original composition during the settling process owing to differences in size and specific gravity of the particles of the components.

TABLE 1. THE EFFECT OF CERTAIN SUBSTANCES WHEN ADDED IN QUANTITIES APPROXIMATELY EQUAL TO THAT OF ACID LEAD ARSENATE, ON THE TOXICITY OF THE LATTER AS INDICATED BY THE MEDIAN LETHAL DOSES FOR THE FOURTH-INSTAR SILKWORM

| Substance added to acid lead arsenate | Median lethal dose[1] | Relative toxicity based upon acid lead arsenate as 1.0 |
|---|---|---|
| | *Mg. per gram* | |
| No addition | 0.086 | 1.00 |
| Calcium hydroxide | 0.074 | 1.16 |
| Calcium caseinate | 0.062 | 1.39 |
| Hydrated ferric oxide | 0.093 | 0.92 |

[1]In milligrams of acid lead arsenate per gram of body weight necessary to produce 50 per cent mortality.

In Figure 16 three mortality curves, B, C, and D, show respectively the apparent effect of the addition of calcium hydroxide, calcium caseinate, and hydrated ferric oxide on the toxicity of acid lead arsenate, the mortality curve of which, when used alone is shown by A. Both calcium hydroxide and calcium caseinate appear to increase the toxicity of acid lead arsenate, whereas hydrated ferric oxide seems to decrease it slightly. The median lethal doses of acid lead arsenate alone and in combination with approximately equal weights of these three substances are given in Table 1. Based upon the median lethal doses, acid lead arsenate with calcium hydroxide was 1.16 times as toxic, with calcium caseinate 1.39 times, and with hydrated ferric oxide 0.92 times as toxic as acid lead arsenate alone. Curves B and C are considered more reliable than Curve D because they are based on larger numbers of cases. The data on additions of precipitated sulfur and dry Bordeaux mixture were insufficient for plotting curves, but they indicate that the former may increase the toxicity of acid lead arsenate and the latter may decrease it. One fact stands out very clearly; i. e., none of the five substances tested had any very great effect on the toxicity of acid lead arsenate for the fourth-instar silkworm.

In view of the small differences observed, the chief defect of the present work lies in the fact that the comparisons were not made strictly in parallel. It is therefore planned to repeat the work during the coming

season with a modified and improved technique in order to get results of greater reliability and also to obtain information upon other preparations.

THE RELATIVE SUSCEPTIBILITY OF DIFFERENT SPECIES OF INSECTS TO THE SAME STOMACH POISONS. After the sandwich method with the fourth-instar silkworm had been advocated for determining the relative toxicity of stomach poisons, questions were raised as to whether the results secured with it would be applicable to other insects and whether other species could be used in the method. Accordingly, as opportunity permitted during the season of 1931, several species of lepidopterous larvae were brought in from the field and attempts were made to determine their susceptibility to the standard acid lead arsenate. Tests were made with the last instar of each of the following species: Eastern tent caterpillar (*Malacosoma americana* Fab.), fall webworm (*Hyphantria cunea* Drury), walnut caterpillar (*Datana integerrima* G. & R.), and catalpa sphinx (*Ceratomia catalpae* Boisd.). It was found that all these caterpillars can be utilized in the sandwich method.

Time and material were lacking for accurate determination of the median lethal dose of acid lead arsenate for the first three of the above-mentioned species. However, the results indicated that the last instar of the eastern tent caterpillar and the fall webworm are decidedly more resistant to acid lead arsenate than is the fourth-instar silkworm. It is believed that the median lethal dose for the former species will be found to lie between 0.15 and 0.21 mg. per gram; and that for the latter it will be greater than 0.16 mg. per gram, whereas the median lethal dose for the fourth-instar silkworm is only 0.09 mg. per gram. On the other hand, the walnut caterpillar and the catalpa sphinx were less resistant to acid lead arsenate than the silkworm. The median lethal dose for the walnut caterpillar will probably be somewhat less than 0.05 mg. per gram. In the case of the catalpa sphinx the data were sufficient for the plotting of a mortality curve (Fig. 17B), which is compared with the mortality curve for the silkworm (Fig. 17A). The median lethal dose in curve B is 0.062 mg. per gram.

It is evident from the foregoing indications that the median lethal dose of acid lead arsenate may vary widely according to the species. This conclusion is not surprising because earlier quantitative results have pointed to great differences in susceptibility among different species. Campbell (*1*) showed that another species of *Datana* (*D. ministra* Drury) is more susceptible to sodium arsenite than is the eastern tent caterpillar, which is in line with the present results. Campbell also has some unpublished results which indicate that the median lethal dose

of acid lead arsenate for the adult differential grasshopper (*Melanoplus differentialis* Thos.) may be ten times or more as great as that for the silkworm. Richardson and Haas (*6*) recently found the median lethal dose of acid lead arsenate for potato beetle (*Leptinotarsa decemlineata* Say) larvae to be 0.30 mg. per gram, or about three times that for the silkworm.

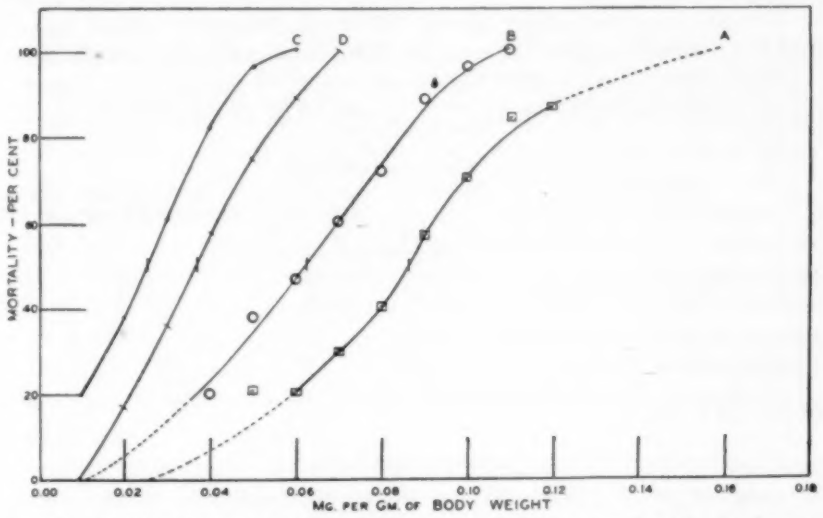



FIG. 17.—Relative toxicity of acid lead arsenate and cuprous cyanide for the fourth-instar silkworm and the last-instar catalpa sphinx caterpillar. Curve A (318 insects), acid lead arsenate, silkworm; B (189 insects), acid lead arsenate, catalpa sphinx; C (64 insects), cuprous cyanide, catalpa sphinx; D (18 insects), cuprous cyanide, silkworm.

Although the median lethal dose of a given stomach poison may vary widely among different species, it is possible that the relative toxicity of a series of stomach poisons may be about the same in related species. Some information was obtained on this possibility by determining the median lethal dose of cuprous cyanide for the catalpa sphinx. (The sample of cuprous cyanide used was the same as that previously tested by Campbell with the silkworm.) Figure 17 gives mortality curves for both the catalpa sphinx and the silkworm poisoned with acid lead arsenate and with cuprous cyanide. Curves A and B show that the silkworm (A) is more resistant to acid lead arsenate than is the catalpa sphinx (B) and curves C and D[2] show that the former insect (D) is also

[2]This curve was plotted by the present writer from data obtained on the fourth-instar silkworm in July, 1929, by Dr. F. L. Campbell.

more resistant than the latter (C) to cuprous cyanide. When ratios of the median lethal doses were calculated (Table 2), the relative toxicity of the two compounds for both species was found to be about the same. The relative susceptibility of the two species to both compounds was necessarily also about the same. Thus one instance has been found where, although median lethal doses differ, relative toxicity and susceptibility are similar.

TABLE 2. THE RELATIVE TOXICITY OF ACID LEAD ARSENATE AND CUPROUS CYANIDE TO THE FOURTH-INSTAR SILKWORM AND TO THE LAST-INSTAR CATALPA SPHINX CATERPILLAR, AS SHOWN BY THE RATIOS OF THE MEDIAN LETHAL DOSES

| Substance | Median lethal does[1] | | Relative susceptibility based upon silkworm as 1.0 |
|---|---|---|---|
| | Silkworm | Catalpa sphinx | |
| | *Mg. per gram* | *Mg. per gram* | |
| Acid lead arsenate | 0.086 | 0.062 | 1.39 |
| Cuprous cyanide | 0.037 | 0.025 | 1.48 |
| Relative toxicity based upon acid lead arsenate as 1.0 | 2.32 | 2.48 | |

[1]In milligrams of acid lead arsenate per gram of body weight necessary to produce 50 per cent mortality.

## LITERATURE CITED

1. CAMPBELL, F. L. 1926. The practicability of quantitative toxicological investigations on mandibulate insects. Jour. Agr. Research 32: 359–366.
2. ————. 1930. A comparison of four methods for estimating the relative toxicity of stomach poison insecticides. Jour. Econ. Ent. 23: 357–370.
3. ———— and FILMER, R. S. 1929. A quantitative method of estimating the relative toxicity of stomach-poison insecticides. Trans. IV. Internatl. Cong. Ent. 523–533, illus.
4. GINSBURG, J. M., and MANN, R. F. 1931. Studies with hydrated ferric oxide as corrective and sticker for lead arsenate and nicotine tannate. Jour. Econ. Ent. 24: 695–701.
5. MILLS, F. C. 1924. Statistical methods. 604 p. New York.
6. RICHARDSON, C. H., and HAAS, L. E. 1931. The toxicity of acid lead arsenate to the larva of the Colorado potato beetle. Jour. Econ. Ent. 24: 732–736.
7. STELLWAAG, F. 1931. Giftigkeit und Giftwert der Insecticide. VI. Teil: Ziele und besondere Methodik bei der Bestimmung der Giftigkeit im Individualversuch. Ztschr. angew. Ent. 18: 113–132, illus.

Professor O'Kane called for the reading of the next paper.

# THE USE OF MINERAL OILS FOR BETTER DUSTS[1]

By W. P. FLINT, *Chief Entomologist, State Natural History Survey, Entomologist, Ill. Agricultural Experiment Station* and M. D. FARRAR, *Research Entomologist, State Natural History Survey*

In the course of our experimental work on Oriental fruit moth control an attempt was made to develop dusts with better sticking qualities than those ordinarily used for peach tree dusting. One of the methods tried to develop such dusts was by the addition of small quantities of mineral oil. It was found that such mixtures could be made and that the mineral oil dusts could be applied with an ordinary orchard duster, giving a much better stick than the same dusts without mineral oil.

In most of the early work the mineral oils used with dusts were of the highly refined type, that is, sulphonated oils containing only a very small amount of unsaturated hydrocarbons. Oils of the drying oil type have not been found satisfactory for this purpose. Mineral oils of from 80 to 110 seconds viscosity have been found most desirable for dusting mixtures. White or saturated oils may be used but the unsaturated oils or so called straw oils have not caused injury in orchard dusting mixtures.

During the winter of 1929–1930 a large series of laboratory tests were run in which dusting materials were combined with the light lubricating straw oils. The greenhouse tests on peach with such dusts did not produce injury and it was felt that the oils would be safe to use in the field. A number of tests with such oil dusts were carried on in 1930 on apple, peach, potato and other plants without any injury resulting. Combinations of oils with most of the standard orchard dusts have now been tested, including combinations of sulphur and oil; sulphur, arsenate of lead, oil; sulphur, lime, lead, oil; arsenate of lead, lime, monohydrated copper sulphate and oil, and others. Because of the physical condition of the dust and the fact that the material must remain in a state where it can be applied as a dust, it has not been found practical to combine more than 5% by weight of oil with the dusts. In order to combine as much as 5% of oil in sulphur dusts, it has been found necessary to replace a part of the sulphur with hydrated dusting lime or other defloculative material in order to give the mixture sufficient buoyancy for dusting. Dusts containing 60% sulphur or 16% monohydrated copper sulphate carry sufficient fungicidal material to give satisfactory control of many of the orchard diseases.

[1]Contribution No. 12, Project 9, 1, Ill. State Natural History Survey.

A dust containing 5% oil of the above specifications makes a combination which is easily handled by the standard orchard dusters. The dusts do not have quite the floating buoyancy characteristic of most orchard dusts which do not contain oil. The particles are finely divided and have sufficient float to enable an experienced operator to distribute the dust very evenly over the tree. A less amount of dust can be used and an equally good coverage obtained. The coverage with carefully applied oil dusts is very uniform. The superiority of its sticking qualities is easily demonstrated either in the laboratory or in the field. So far most of our tests with oil dusts have been made in orchards, although a small series of tests have been carried on in dusting potatoes, beans and cucumbers.

Extensive tests of oil dusts on peaches have shown such dusts to be superior to other materials, including standard sprays. Where such dusts have been used no arsenical injury has occurred, the growth of the trees has been excellent, and the foliage has remained in a fine condition throughout the season. Three years work with such dusts in peach orchards has convinced us of their value. A number of our larger orchardists used them either in part or wholly last year and so far as we know all of these men will use them exclusively next year.

These dusts have given fairly good control of second brood codling moth but are not equal to sprays in this case. The control of curculio has been equal to that obtained by standard sprays and the control of Oriental fruit moth has been as good as that obtained with any other material. Diseases of peach were controlled equally well as with the standard sprays.

It is not possible to prepare a satisfactory oil dust in the ordinary hopper mixer now used on some makes of dusting machines. It is absolutely necessary that the oil be thoroly mixed throughout the dust. To accomplish this we have found it necessary to use one of the standard makes of dust mixers. The oil can be added to a small amount of the mixed materials and then fed into the mixer with the remainder of the dust, or the oil may be sprayed in the form of a fine spray into the hopper of the dust mixer as the other materials are being added.

While the oil dusts are heavier and somewhat more sticky than ordinary dusts, they do not pack in storage. Sacked samples which we have held over for two years have remained in excellent condition.

Mr. Thompson asked if oil had been used with lime mixture. Mr. Flint replied that it had and could be applied up to 6% of its weight.

Mr. W. W. Stanley stated that he had used cryolite and asked about

the efficiency of the Bean duster. Mr. Flint stated that mixtures made with the Bean duster did not give satisfactory results.

Professor O'Kane gave a few introductory remarks concerning the presentation of papers on insect physiology. He then called for the reading of the next paper.

## THE EFFECT OF SOME GASES ON THE TRACHEAL VENTILATION OF GRASSHOPPERS[1]

By E. R. McGovran, *Urbana, Illinois*

ABSTRACT

$CO_2$, $CS_2$, HCN and Nicotine in certain concentrations increased the volume of air inhaled into the tracheal system by the respiratory movements of the grasshoppers that were studied. Minimum lethal concentrations of HCN and $CS_2$ temporarily increased the tracheal ventilation, but this was followed by a gradual decrease as the insect became less and less active.

The change in the volume of air that enters the tracheal system of an insect when it is exposed to toxic gases might well be considered in fumigation and in many spraying and dusting operations.

The effect of gases on the respiratory movements of insects was studied by Walling (1906). She observed that an atmosphere of $CO_2$ stopped the respiratory movements of grasshoppers, but that the insects recovered if placed in air after as long as two days confinement in the gas. Buddenbrock and Rohr (1922) observed the respiratory movements of *Dixippos morosus* and found that the rate increased irregularly at various concentrations of $CO_2$ up to 30%. Hazelhoff (1928) found that 2 or 3% $CO_2$ opened the tracheal valves and 7 or 10% $CO_2$ initiated respiratory movements in resting *Periplaneta americana*. Brinley and Baker (1927) state that methyl acetate is found to keep the spiracles of *Melanoplus differentialis* open in an atmosphere of HCN. Demoll (1927) found that Maybeetles were killed in less time when the head and thorax were exposed to Chlorine than when just the abdomen was exposed.

The inhalation and exhalation of air by the respiratory movements of insects has been studied by Krogh (1920), Lee (1925), McArthurs (1929) and others. Stahn (1928) measured the volume of air exhaled by a single breathing movement of *D. morosus* and found it varied between 0.15 c. mm. and 2.00 c. mm. McGovran (1931) found *Chorto-*

[1]A contribution from the Dept. of Zoology and Entomology, Iowa State College, mes, Iowa.

*phaga viridifasciata* passed an average of 0.22 cc. of air through their tracheal system per minute per gram of body weight.

TABLE 1. TYPICAL EFFECTS OF $CO_2$ ON THE TRACHEAL VENTILATION OF GRASSHOPPERS AT 28° C.

| Test No. | Species | Duration of normal test in min. | Ave. C.C. normal tracheal ventilation per min. per gr. of insect | Per cent $CO_2$ | Minutes in $CO_2$ | Ave. C.C. Tracheal ventilation per gr. per min. in $CO_2$ | Direction of air movement through tracheal system | Condition of insect at end of test |
|---|---|---|---|---|---|---|---|---|
| 1 | C.V.[1] | 32 | 0.13 | 15 | 37 | 0.07 | Reversed | Active |
| 2 | C.V. | 34 | 0.10 | 15 | 32 | 0.27 | Normal[4] | Active |
| 3 | A.S.[2] | 93 | 0.07 | 15 | 24 | 0.24 | Reversed | Active |
| 4 | A.S. | 28 | 0.10 | 15 | 5 | 1.49 | Normal | Active |
| 5 | D.C.[3] | 54 | 0.16 | 15 | 3 | 0.76 | Normal | Active |
| 6 | "[5] | " | 0.16 | 15 | 7 | 0.12 | " | " |
| 7 | " | " | " | 15 | 10 | 0.21 | Reversed | " |
| 8 | " | " | " | 15 | 9 | 0.34 | " | " |
| 9 | " | " | " | 15 | 5 | 0.47 | " | " |
| 10 | " | " | " | 15 | 8 | 0.26 | " | " |
| 11 | D.C. | 26 | 0.25 | 15 | 3.5 | 1.17 | Reversed | Active |
| 12 | " | " | " | 15 | 3.5 | 1.16 | " | " |
| 13 | " | " | " | 15 | 3.5 | 1.19 | " | " |
| 14 | " | " | " | 15 | 5 | 0.82 | " | " |
| 15 | " | " | " | 15 | 6 | 0.68 | " | " |
| 16 | D.C. | 37 | 0.15 | 1 | 8 | 0.13 | Normal | Active |
| 17 | " | " | " | 1 | 9 | 0.13 | " | " |
| 18 | " | " | " | 1 | 5 | 0.14 | " | " |
| 19 | " | " | " | 1 | 8 | 0.12 | " | " |
| 20 | " | " | " | 1 | 4 | 0.17 | " | " |
| 21 | " | " | " | 1 | 4 | 0.14 | " | " |

[1] *Chortophaga viridifasciata* De Geer.
[2] *Arphia sulphurea* Fab.
[3] *Dissosteira carolina* Linne.
[4] Normal indicates that the air was inhaled into the thorax and exhaled from the abdomen.
[5] Ditto marks indicate that the same insect was used as in the preceding test. The tests were run in sequence without removing the insect from the apparatus.

APPARATUS AND PROCEDURE. The apparatus was the same as that used by the author in a previous investigation, McGovran (1931). The procedure was the same as that described in this paper except that the gases studied were placed in the chamber that enclosed the head and thorax of the insect. The results with nicotine were obtained by placing nicotine, 100% free nicotine, in the chamber below the head and thorax of the insect.

All the insects used were adult female grasshoppers. The tests were run at 28° C.

RESULTS. In Table 1 are found the results of 21 tests which are typical of the 86 tests of the effect of $CO_2$ on grasshoppers and illustrate the different reactions of the insects to the gas. The rate of tracheal

ventilation was increased in 93% of the tests with 15% $CO_2$. The maximum increase was slightly more than 20 times the normal. In 72% of the tests with 15% $CO_2$ the direction of the air movement through the tracheal system was reversed, that is, the air was inhaled principally into the abdomen and exhaled principally from the thorax. The direction of the air movement through the tracheal system after the removal of the $CO_2$ was observed and found to be normal. The rate also returned to approximately normal in every instance.

TABLE 2. TYPICAL EFFECTS OF $CS_2$ ON TRACHEAL VENTILATION OF ADULT FEMALE *Arphia sulfurea* FAB. AT 28°C

| Test No. | Wt. of insect in grams | Duration of normal test in minutes | C.C. ventilation per min. per gram, normal | Percent $CS_2$ in chamber enclosing thorax | Min. in $CS_2$ | C.C. ventilation per min. per gram in $CS_2$ | Direction of air movement through tracheal system | Condition of insect at end of test |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.73 | 66 | 0.07 | 3 | 14 | 0.11 | Normal | Active |
| 2 | " | " | " | 3 | 13 | 0.09 | Normal | Active |
| 3 | " | " | " | 3 | 12 | 0.12 | Normal | Active |
| 4 | 1.08 | 42 | 0.07 | 8 | 8 | 0.21 | Normal | Active |
| 5 | " | " | " | 8 | 7 | 0.15 | Normal | Active |
| 6 | " | " | " | 8 | 21 | 0.05 | Normal | Active |
| 7 | " | " | " | 8 | 9 | 0.01 | Normal | Motionless |

The effect of 1% $CO_2$, as illustrated by tests 16–21 in Table 1, was to increase the average rate of tracheal ventilation about 5%. No instance of the reversal of the direction of air movement through the tracheal system was observed.

Sub-lethal concentrations of $CS_2$, tests 1–3 in Table 2, produced an average increase of 41% in the rate of tracheal ventilation during the first 5 minutes the insects were exposed to the gas. The average rate continued at slightly below this level for 30 minutes or longer, when the tests were stopped. Concentrations of $CS_2$ that rendered the insect motionless by the end of a series of tests produced an average of 62% increase in the rate of tracheal ventilation during the first 5 minutes. This initial increase was followed by a gradual fall as the insects became less and less active, tests 4–7 in Table 2. The direction of the air movement through the tracheal system was not reversed. The 7 tests given in Table 2 are typical of the two types of reactions observed in the 46 tests that were run with $CS_2$.

As illustrated in Table 3, 0.2% HCN produced an average decrease of 14% in the rate of tracheal ventilation in the first 5 minutes in the gas, followed by a rapid fall as the insects were killed quickly, tests 1–3 in Table 3. 0.1% HCN during the first 5 minutes produced a 15% rise in the average rate of tracheal ventilation which was followed by a

gradual fall as the insect was stupefied by the gas, tests 4–6 in Table 3. The 6 tests given in Table 3 are typical of the results of 31 tests that were run with HCN.

TABLE 3. TYPICAL EFFECTS OF HCN ON THE TRACHEAL VENTILATION OF GRASSHOPPERS AT 28°C.

| Test No. | Species | Wt. in grams | Duration of normal test in minutes | Normal tracheal ventilation per gr. per minute in C.C. | % HCN in chamber enclosing thorax | Min. in HCN | C.C. tracheal ventilation per gr. per min. in HCN | Direction of air movement through tracheal Sys. | Condition of insect at end of test |
|---|---|---|---|---|---|---|---|---|---|
| 1 | D.C.[6] | 1.42 | 8 | 0.56 | 0.2 | 3 | 0.24 | Normal | Active |
| 2 | " | " | " | " | 0.2 | 10 | 0.07 | " | " |
| 3 | " | " | " | " | 0.2 | 5 | 0.01 | " | Motionless |
| 4 | M.B.[7] | 1.37 | 27 | 0.13 | 0.1 | 2 | 0.24 | Normal | Active |
| 5 | " | " | " | " | 0.1 | 12 | 0.08 | " | " |
| 6 | " | " | " | " | 0.1 | 24 | 0.04 | " | Motionless |

[6] *Dissosteira carolina* L.
[7] *Melanoplus bivittatus* Say.

In the 41 tests run with nicotine, the nicotine fumes released from 100% free nicotine did not in most cases render the grasshoppers inactive in the time, 33 to 120 minutes, they were exposed, but one insect died after 4 minutes exposure to the nicotine fumes and another one died shortly after being removed from the apparatus. There was an average increase in the rate of tracheal ventilation of 70% in the first 5 minutes in the nicotine vapor which was followed by a gradual fall to below normal in about one-half of the specimens that were studied. In one instance there was a reversal of the direction of air movement.

DISCUSSION. The apparatus as operated in these tests recorded only the movement of air completely through the tracheal system. In many of the tests, especially with 15% $CO_2$, the insect inhaled and exhaled rapidly and deeply, but did not produce a correspondingly large movement of air into the thorax and out of the abdomen. This was most noticeable when the direction of air movement through the tracheal system was being reversed, tests 6 and 7 in Table 1. First, the air movement in the normal direction would be reduced until it stopped entirely, but air was still rapidly inhaled and exhaled with each spiracle apparently performing equally as inhalatory and exhalatory orifices. After a short period of this type of breathing more air began to be exhaled from the thorax than was inhaled into the thorax which was a reversal of the normal.

Three of the specimens that were studied normally inhaled principally into the abdomen and exhaled principally from the thorax. One of these was parasitized by three full-grown *Sarcophaga marginata* Ald.[2] larvae, another was gravid and the third appeared normal upon dissection.

SUMMARY. In 93% of the tests 15% $CO_2$ produced an increase in the rate of tracheal ventilation. The maximum increase for any period was slightly more than 1900%. 72% of the tests showed a reversal of the direction of air movement through the tracheal system.

One per cent $CO_2$ increased the average rate of tracheal ventilation about 5%, but it did not reverse the direction of the air movement through the tracheal system in a single instance.

Sub-lethal concentrations of $CS_2$ and nicotine increased the average rate of tracheal ventilation 41% and 70% respectively, during the first 5 minutes the insects were exposed to the gas.

High concentrations (0.2%) of HCN which killed the insect quickly produced an average fall of 14% in the rate of tracheal ventilation in the first 5 minutes the insects were exposed in the gas followed by a much more rapid decrease.

Concentrations of $CS_2$ and HCN which killed the insects slowly produced an average increase of 62% and 15%, respectively, in the rate of tracheal ventilation in the first 5 minutes followed by a gradual decrease which continued until the insects became motionless.

ACKNOWLEDGMENTS. The author takes this opportunity to thank Dr. C. H. Richardson under whose direction this study has been carried on, for the many helpful suggestions he has made. The author also wishes to thank the other members of the Faculty of the Dept. of Zoology and Entomology of Iowa State College for the assistance they have given in carrying on this research.

## REFERENCES

BRINLEY, F. J., and BAKER, R. H. 1927. Some Factors Affecting the Toxicity of Hydrocyanic Acid for Insects. Biol. Bull. Vol. 53, pp. 201-207, 4 fig.

BUDDENBROCK, W. v., and ROHR, G. v. 1922. Die Atmung von *Dixippus morosus*. Zeit. Alleg. Physiol. Vol. 20 pp. 111–160, 20 fig.

DEMOLL, R. v. 1927. Untersuchungen uber die Atmung der Insekten. Zeit. Biol. Vol. 87, pp. 8–22, 2 fig.

HAZELHOFF, E. H. 1928. $CO_2$ a Chemical Accelerating the Penetration of Respiratory Insecticides into the Tracheal System by Keeping Open the Tracheal Valves. Jour. Econ. Entom. Vol. 21, p. 790.

KROGH, A. 1920. Die Kombination von mechanischer Ventilation mit Gasdiffusion nach Versuchen an Dytisquelarven. Pfluger's Archiv Physiol. Vol. 179, pp. 113–120, 2 fig.

[2]Species determined by H. H. Ross, State Natural Hist. Survey, Urbana, Ill.

LEE, M. O. 1925. On the Mechanism on Respiration in Certain Orthoptera. Jour. Exp. Zool. Vol. 41, pp. 125–154, 2 fig.

MCARTHURS, J. M. 1929. An Experimental Study of the Functions of the Different Spiracles in Certain Orthoptera. Jour. Exp. Zool. Vol. 53, pp. 117–128.

MCGOVRAN, E. R. 1931. A Method of Measuring Tracheal Ventilation in Insects and Some Results Obtained with Grasshoppers. Annals Ent. Soc. Amer. Vol. 24, pp. 751–761, 2 fig.

STAHN, I. 1928. Uber die Atmungsregulation, besonders die Kohlensaureregulation bei *Dixippos morosus* und *Aeschna grandis*. Zool. Jahrb., Abt. Allg. Zool. und Physiol. Vol. 46, pp. 1–86.

WALLING, E. V. 1906. The Influence of Gases and Temperature on the Cardiac and Respiratory Movements in the Grasshopper. Jour. Exp. Zool. Vol. 3, pp. 621–629.

Professor O'Kane asked Mr. McGovran to describe the technique used in these experiments. Mr. McGovran replied that such a description was being published in the December issue of the Annals of the Entomological Society of America. He gave a brief description of his technique for the benefit of the members present. Dr. Moore asked if gas had been applied to the abdominal side of the grasshopper. Mr. McGovran replied that it had not.

Professor O'Kane called for the reading of the next paper.

## FURTHER STUDIES OF THE EFFECTS OF ELECTRO-MAGNETIC WAVES ON INSECTS[1]

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ABSTRACT

Soil and soil-water heating is likely to prove a limiting factor in the use of electromagnetic waves against soil infesting insects. Irradiation of foliage wall of the apple tree with ordinary white light in the amount of ten foot candles reduced fruit infestation by first brood codling moth 50%. Eggs are, however, frequently deposited in this intensity. Irradiation in the neighborhood of thirty foot candles seems likely to be required to prevent free oviposition. The violet end of the spectrum excites the moth to apparently normal oviposition. The red end tends to produce abnormal activity with some egg laying.

The present paper reports insect reaction to two different regions of what has been called the gamut of electro-magnetic vibration or frequency. In order that the relationship of the frequencies worked with to the frequencies included in the rest of the gamut may be clear, a table

[1]Paper of the Journal Series, New Jersey Agricultural Experiment Station, Department of Entomology.

of frequencies and wave lengths taken from the "Dictionary of Applied Physics" by Glazebrook, published in 1922–1923 is submitted. It is thought that this table is not strictly up to date but that it is sufficiently inclusive to give a pretty definite idea of where, in the gamut, this work was done. The wave-lengths are given in $\mu$. The $\mu$ represents one millionth of a meter or stated in decimals 0.000001 meter.

TABLE OF WAVE-LENGTHS

| Waves | Octave No. | Frequency X $10^{14}$ | Wave-length $\lambda$ $\mu$ |
|---|---|---|---|
| Unknown... | −18 | 1,000,000 | 0.000003 |
| | −17 | 491,520 | 0.000006 |
| | −16 | 245,760 | 0.000012 |
| | −15 | 122,880 | 0.000024 |
| | −14 | 61,440 | 0.000048 |
| $\gamma$ and X..... | −13 | 30,720 | 0.000098 |
| | −12 | 15,360 | 0.000195 |
| | −11 | 7,680 | 0.00039 |
| | −10 | 3,840 | 0.00078 |
| | −9 | 1,920 | 0.00156 |
| | −8 | 960.0 | 0.0031 |
| Unknown... | −7 | 480.0 | 0.006 |
| | −6 | 240.0 | 0.012 |
| | −5 | 120.0 | 0.025 |
| | −4 | 60.0 | 0.05 |
| Schumann | −3 | 30.0 | 0.1 |
| | −2 | 15.0 | 0.2 |
| Ultra-violet | −1 | 7.50 | 0.4 |
| Visible | 0 | 3.75 | 0.8 |
| | +1 | 1.875 | 1.6 |
| Infra-Red | +2 | 0.940 | 3.2 |
| | +3 | 0.470 | 6.4 |
| | +4 | 0.235 | 12.8 |
| | +5 | 0.118 | 25.6 |
| | +6 | 0.059 | 51.2 |
| Infra-Red | +7 | 0.029 | 102.4 |
| | +8 | 0.014 | 204.8 |
| (continued) | +9 | 0.007 | 409.6 |
| | +10 | 0.0035 | 819.2 |
| Unknown | +11 | 0.0018 | 1638.4 |
| | +12 | 0.0009 | 3276.8 |
| | +13 | 0.00045 | 6553.6 |
| | +14 | 0.00022 | 13107.2 |
| | +15 | 0.00011 | 26214.4 |
| | +16 | 0.00005 | 52428.8 |
| | +17 | 0.00003 | 104857.6 |
| Electric | +18 | 0.000015 | 209,715 |
| | +19 | 0.000007 | 419,430 |
| | +20 | 0.000003 | 838,860 |
| | +21 | 0.0000016 | 1,677,720 |
| | +22 | 0.0000008 | 3,355,440 |
| | +23 | 0.0000004 | 6,710,880 |
| | +24 | 0.0000002 | 13,421,760 |
| | +25 | 0.0000001 | 26,843,520 |
| | +26 | 0.0000005 | 53,687,040 |
| | +27 | 0.00000025 | 107,374,080 |

Most of the results on the effect of radio waves fall within the range of octaves *24* to *27*, inclusive, or from frequencies of *20*,000,000 to 2,500,000 but extend beyond octave *27* to a frequency of 1,000,000. Stated in terms of wavelength the range is from 13.4 meters to 300 meters. The results from the study of visible light come from octave 0 in the table with frequencies ranging from above and below 375,000,000,000. Stated in terms of wavelength the range is from 0.4 to 0.76 $\mu$.

At this point it is interesting to note that the known structurally developed receptors for receiving the waves of this gamut are found apparently in the region from 0.40 to 0.76 $\mu$ or the range of vis-

ible light. It is further of great interest to note that these are the bands of waves which are most commonly and efficiently reflected by the common objects with which the insect is surrounded.

RADIO WAVE EFFECTS. In 1931 Headlee (1) made the point that the variable factors underlying lethal effects on certain insects and certain plants were apparently field strength, expressed in volts per linear inch, and frequency, measured in terms of cycles per second. Cycles per second represent the number of changes in electric sign taking place within the limits of a single second. Field strength or field intensity is calculated on a formula and is the product of wavelength in meters X current in amperes X the constant characteristic of the particular machine with which the work is being done. For this machine the constant is 65.5. At this point it should be remembered that the "field" referred to is an electro-static field defined by two 6 inch square electrodes and that it includes the space which lies between them.

The strength or intensity of this field is dependent upon the state of the two variables above mentioned—wavelength and amperage. If either or both decrease the field strength falls correspondingly. If either or both increase the field strength rises correspondingly. In maintaining the same field strength if one of these factors is decreased the other must be correspondingly increased.

The facts adduced in the 1931 paper (1) show that with a constant frequency the speed of kill varies as the field strength, which means as the current volume, because it is the variable concerned in increasing or decreasing the field strength. They also show that with a constant field strength the speed of kill varies as the frequency, which also means as the current volume, because it is the factor which must vary to meet the change in frequency and thus maintain the field strength.

It would, therefore, seem that the speed of kill varies as the current volume. Unfortunately, the matter is not so simple as this because the same current volume at different frequencies has differing degrees of effectiveness. The correlation between speed of kill and current volume is, therefore limited to the same frequency.

Thus it appears that the factors of frequency or wavelength and current volume are with our present information indissolubly combined in the effect of radio waves on certain insects and certain plants and that, while frequency provides the selective agency, current volume furnishes the punch.

Two other facts of great practical importance appear in the data car-

ried by the 1931 paper (1). The first is found in the fact that the speed of kill at 4000 volts per linear inch in certain insects rises with the frequency until about 3,000,000 cycles per second is reached and that upwards of that point increases with extreme slowness. At about 3,000,000 cycles the law of diminishing returns makes its appearance. The second appears in the fact that certain plant seeds, which frequently serve as insect hosts, are totally unaffected at frequencies which readily destroy certain insects, but are completely destroyed at much higher frequencies, such as 12,000,000 to 15,000,000 cycles per second.

At this time the writer is not prepared to undertake a more thoroughgoing analysis of the fundamental underlying factors but wishes to turn attention to the effect of certain other factors that will promptly modify the effects upon insects and plants recorded above. This piece of work was undertaken because of the desire on the part of certain organizations to utilize these radio waves for the purpose of sterilizing soil masses containing living plant roots.

Naturally, the first consideration was the effect of these radio waves at the lowest insect killing frequency and current volume on the soil itself. Inasmuch as the problem involved a lethal degree of heat for the insect, accompanied by a non-lethal degree of heat for the plant roots, and inasmuch as previous studies had shown the danger to plant roots to be due to soil heat, it seemed advisable to study the production of heat in soils subjected to these radio waves. In order to cover the soil field in a minimum length of time and to obtain an idea of the heating effect, synthetic soils were made consisting of various proportions of clay, sand and peat. The clay employed was of an aluminite character, the sand of nearly pure quartz and the peat from peat deposits in cranberry bogs. The soil mixtures were made for the first series of tests with a 5% moisture content. The frequency employed was 2,000,000 cycles per second. The field strength was maintained at 4000 volts per linear inch. The soil composition and the heat developed under treatment covering a period of ten minutes are set forth in Table 1. Each temperature recorded is the average of five temperatures taken under the same set of conditions.

When we recollect that plant roots can stand about 120° F, it is obvious that the heat accumulations in the ten minute period are not high enough in any case to injure the plant roots.

All our past experience with heat devolpment in substances subjected to these radio waves indicates clearly that the presence of certain

TABLE 1. DEVELOPMENT OF HEAT IN SOIL MASSES CONTAINING 5% MOISTURE SUBJECTED TO RADIO WAVES AT A FREQUENCY OF 2,000,000 CYCLES PER SECOND AND A FIELD STRENGTH OF 4,000 VOLTS PER LINEAR INCH

| Soil Composition Proportion | | | Heat Developed in °F Minutes | | | | | | | | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clay | Sand | Peat | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | In 10 minutes | In 9 minutes | Room Temp. in °F |
| 0.0 | 95.0 | 5.0 | 81 | 82 | 83 | 83.5 | 84.5 | 85.6 | 86 | 86.5 | 87 | 87 | 7.0 | 6.0 | 80 |
| 20.0 | 75.0 | 5.0 | 83 | 85.5 | 87.5 | 89.5 | 91.5 | 93.5 | 95 | 96 | 96 | 97 | 17.0 | 14.0 | 80 |
| 45.0 | 50.0 | 5.0 | 83 | 87 | 90 | 93.5 | 96.5 | 99 | 100.5 | 102 | 103 | 104.5 | 24.5 | 21.5 | 80 |
| 70.0 | 25.0 | 5.0 | 84 | 88 | 92 | 96 | 100 | 103 | 105 | 107 | 108 | 109 | 29.0 | 25.0 | 80 |
| 95.0 | 0.0 | 5.0 | 80 | 86 | 92 | 96 | 99 | 102 | 104 | 106 | 107 | 108 | 38.0 | 28.0 | 70 |
| 35.0 | 60.0 | 5.0 | 81 | 84 | 86 | 88 | 90 | 92 | 93 | 94 | 94 | 95 | 25.0 | 14.0 | 70 |
| 75.0 | | 25.0 | 81 | 83 | 85 | 86 | 87 | 88 | 89 | 89 | 90 | 90 | 18.0 | 9.0 | 72 |
| 50.0 | | 50.0 | 80 | 81 | 82 | 84 | 85 | 86 | 86.5 | 87 | 87.5 | 88 | 16.0 | 8.0 | 72 |
| 25.0 | | 75.0 | 80 | 82 | 83 | 84 | 84.5 | 85.5 | 86 | 86 | 86 | 86 | 14.0 | 6.0 | 72 |
| 0.0 | | 100.0 | 80 | 82 | 83 | 84 | 84 | 85 | 85.5 | 85.5 | 85.5 | 85.5 | 13.5 | 5.0 | 72 |

amounts of water greatly contributes to the amount of detectable heat developed in a given time. The next step was, therefore, to increase the moisture content of the synthetic soils under test. They were given a 20% moisture content on a weight basis and treated as set forth in the preceding study. Table 2 sets forth the results.

This table shows that heat development in all of these synthetic soils is both rapid and high and that in some of them reaches a point, in a sufficiently short length of time, to render the process dangerous to plant roots. Remembering that the length of exposure necessary to kill some grubs may be as long as five minutes we find the temperatures ranging from 117° F. in the sand and clay and 180° F. or above in mixtures carrying large amounts of peat.

This study seems to indicate unmistakably that moisture content of the soil ball will form a decided limiting factor in the use of radio waves for clearing the soil ball about the roots of living plants from insect infestation. It is perhaps worthwhile to note that the development of detectable heat in these soils in the presence of as much as 20% moisture is correlated with the size of the particle. The largest particle is, of course, in the sand, the next largest in the clay and the smallest in the peat.

Since water seems to function so decidedly in the development of detectable heat in the various substances with which work has been done, it seemed well to investigate the rate at which water itself develops heat when subjected to these radio waves. Accordingly, triple distilled water was utilized as the material with which to secure data on this question. Water of this character was subjected to various frequencies ranging from 1,000,000 to 12,097,000 cycles per second with the common field strength of 4000 volts per linear inch. Five runs were made at each frequency for a period of ten minutes each and the results averaged. The results are set forth in Table 3.

Owing to high specific heat the temperature in water rises comparatively slowly but this table shows a distinct rise. In view of the limited amount of data submitted in this table it is not possible to draw conclusions as to the relation of ratios between current volumes and ratios between resultant heat accumulations.

Light Wave Effects. Excessive abundance of the codling moth seemed to demand that nothing should be overlooked as a possibility for controlling that insect. The interesting results secured by Herms (2) indicate that electric lights illuminating apple trees to the amount of four

TABLE 2. DEVELOPMENT OF HEAT IN SOIL MASSES CONTAINING 20% MOISTURE SUBJECTED TO RADIO WAVES AT A FREQUENCY OF 2,000,000 CYCLES PER SECOND AND A FIELD STRENGTH OF 4,000 VOLTS PER LINEAR INCH

| Soil Composition Proportion | | | Heat Developed in °F Minutes | | | | | | | | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clay | Sand | Peat | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | In 10 Min. | In 9 Min. | Room Temp. in °F |
| 0.0 | 95.0 | 5.0 | 83 | 100 | 107 | 112 | 117 | 120 | 124 | 126 | 128 | 130 | 39.0 | 37.0 | 81 |
| 20.0 | 75.0 | 5.0 | 96 | 105 | 112 | 118 | 123 | 128 | 132 | 135 | 138 | 140 | 60.0 | 45.0 | 81 |
| 45.0 | 50.0 | 5.0 | 95 | 103 | 110 | 116 | 120 | 124 | 127 | 129 | 131 | 133 | 52.0 | 38.0 | 81 |
| 70.0 | 25.0 | 5.0 | 98 | 108 | 117 | 125 | 131 | 136 | 139 | 142 | 145 | 147 | 66.0 | 48.0 | 81 |
| 95.0 | 0.0 | 5.0 | 101 | 112 | 121 | 127 | 132 | 136 | 140 | 143 | 145 | 146 | 66.0 | 46.0 | 81 |
| 35.0 | 60.0 | 5.0 | 96 | 101 | 106 | 110 | 113 | 116 | 118 | 120 | 122 | 123 | 41.0 | 26.0 | 81 |
| 75.0 | | 25.0 | 103 | 120 | 134 | 145 | 152 | 158 | 163 | 167 | 169 | 171 | 90.0 | 68.0 | 81 |
| 50.0 | | 50.0 | 110 | 134 | 157 | 172 | 182 | 190 | 196 | 200 | 202 | 203 | 127.0 | 93.0 | 76 |
| 25.0 | | 75.0 | 111 | 136 | 155 | 169 | 181 | 188 | 194 | 195 | 196 | 196 | 120.0 | 85.0 | 76 |
| 0.0 | | 100.0 | 107 | 130 | 155 | 165 | 178 | 187 | 194 | 198 | 200 | 200 | 124.0 | 91.0 | 76 |

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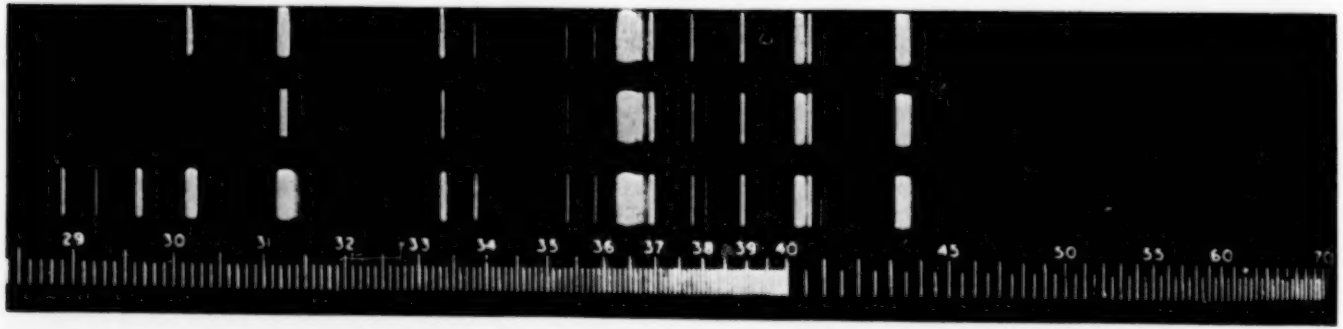


Chart taken from General Electric Company Bulletin 105B showing mercury vapor lamp spectrum with the kind of glass used. The particular spectrum used is represented by second line from the bottom.

foot candles resulted in a reduced amount of codling moth infestation. An effort was, therefore, made to see whether control of codling moth could be secured by means of orchard lighting.

A large Grimes Golden apple tree standing in the midst of a heavily infested orchard was selected for the try out. Telegraph poles were set on the corners of a square surrounding this tree. Lights were mounted on these poles with reflectors throwing the rays against the foliage wall of the tree in such a way as to produce a rather uniform degree of lighting. Other trees standing in the rows about this tree were utilized for the study of reduced amounts of lighting. These light sockets were first equipped with 500 watt Mazda C lamps, the characteristic curve of which is shown in Figure 18. With this installation the foliage wall of the tree was uniformly lighted in the amount of about ten foot candles. This installation was put in operation about the time the codling moth got on the wing and was continued throughout the first brood period. At the end of the first brood period the fruit infestation on this tree was approximately half of that which was characteristic of the surrounding orchard but inasmuch as a one-half reduction still left about a 40% infestation the control obtained could not be said even to approach the proportions of a satisfactory result.

After the close of the first brood, the lighting was switched to Mazda CX lamps, the characteristic curve of which is shown in Figure 18. The principal difference between the Mazda C and Mazda CX lies in a heavier proportion of the light from the Mazda CX occurring in the violet end of the spectrum. Determining the effect of the Mazda CX by observations of codling moth activity, it did not seem that the moth activity under the Mazda CX showed any particular difference from moth activity under the Mazda C.

Attention was then turned to certain phases of the visible spectrum. Mercury daylight lamps, whose characteristics are shown in Plate 10, were then installed and the following observations were made by Mr. F. M. Thompson, Jr.

"*July 21.* Lights were switched on at dusk when first moth activity was noted. An occasional moth was seen on the outer edge of the foliage in direct light. Few were noted flying on the inside of the tree. Moths seemed to be less active than under ordinary lights. In trees about lighted areas an occasional moth was seen. Further away from light activity seemed to cease with darkness.

TABLE 3. DEVELOPMENT OF HEAT IN DISTILLED WATER WHEN SUBJECTED TO RADIO WAVES OF VARYING FREQUENCIES AND A FIELD STRENGTH OF 4,000 VOLTS PER LINEAR INCH

| Date | Frequency in Cycles per Second | Heat Developed in °F by Minutes Exposed | | | | | | | | | | | Total in 10 Minutes | Room Temp. in °F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Start | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | |
| 1/19/31 | 1,000,000 | 80 | 82 | 83.6 | 84 | 86 | 86.8 | 87.6 | 88.6 | 88.6 | 88.8 | 89.2 | 9.2 | 80 |
| 1/19/31 | 2,000,000 | 81.6 | 83.8 | 85.8 | 87.6 | 89 | 90.2 | 91.2 | 91.8 | 92.2 | 93.2 | 94.2 | 12.6 | 82 |
| 1/19/31 | 3,000,000 | 76.8 | 78.6 | 80.4 | 82.6 | 84.2 | 86.2 | 88.6 | 90.6 | 92.2 | 94.2 | 95.8 | 19.0 | 74 |
| 1/19/31 | 5,000,000 | 79.2 | 90.7 | 98.7 | 106.4 | 112.7 | 119.7 | 121.5 | 124.7 | 127.0 | 129.0 | 131.0 | 51.8 | 78 |
| 1/20/31 | 6,000,000 | 76.0 | 81.2 | 86.6 | 91.6 | 95.6 | 98.8 | 101.8 | 104.0 | 105.6 | 107.0 | 108.0 | 32.8 | 76 |
| 2/23/31 | 7,500,000 | 83.2 | 92.2 | 99.4 | 105.0 | 110.8 | 115.4 | 119.6 | 123.4 | 126.8 | 130.2 | 133.2 | 50.0 | 83 |
| 2/23/31 | 8,570,000 | 80.0 | 87.6 | 94.4 | 100.6 | 106.2 | 111.0 | 115.6 | 119.4 | 123.0 | 127.8 | 128.2 | 48.2 | — |
| 1/20/31 | 12,097,000 | 76.0 | 82.6 | 88.4 | 93.6 | 97.6 | 101.2 | 104.4 | 107.4 | 110.2 | 112.2 | 114.2 | 38.2 | 77 |

"*July 22.* Lights were switched on after dark, after moth activity had apparently ceased. No moths were seen either in the lighted or unlighted trees.

"*July 23.* Lights were turned on at dusk while moths were active. Oviposition was very heavy all the time the lights were on, both in areas

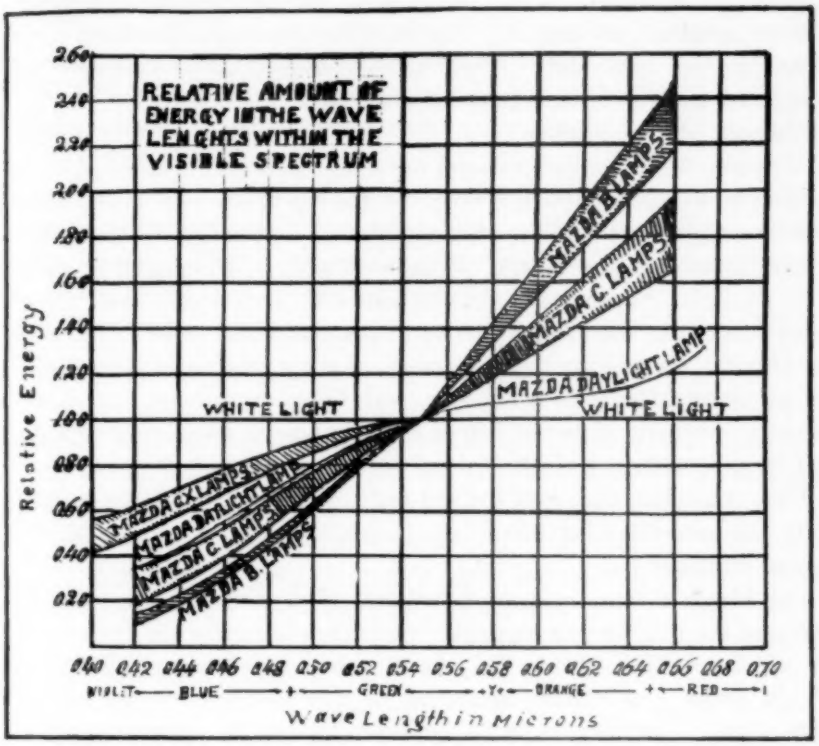


FIG. 18.—Chart taken from General Electric Company: Theory and Characteristics of Mazda Lamp with Modification to Represent Mazda CX.

around the tree and on the lighted tree. Three eggs were seen deposited in direct light. Eggs were found in almost every part of the tree."

These observations seem to indicate that the light derived from the mercury lamp seems rather to stimulate oviposition than to retard it.

At this point the mercury vapor lamps were replaced with Mazda C 1000 watt bulbs painted red. The bulk of the light transmitted by these red painted bulbs ranged from 0.49 $\mu$ to 0.76 $\mu$, with the heavy emission in the orange and red ranging from 0.59 $\mu$ to 0.76 $\mu$. The following observations were made on the light transmitted by them.

"*July 28.* With moth activity normal throughout the orchard at dusk, the lights were switched on. Moths were quite active in the lighted tree. Most of the activity seems to be in the outer branches and in the tops of the tree. Oviposition was heavy in direct light. As darkness increased, activity ceased in trees around lighted tree and there seemed to be an attraction of the moths to the lighted area. No moths were seen flying into the light but the number of moths in the lighted tree increased until about an hour after dark. Their activity seemed to be restricted to flying and no oviposition was noted after dark.

"*July 29.* Moths inactive.

"*July 30.* The observations were the same as on July 28th except for the fact that oviposition was frequent in the top of the tree where moth activity was greatest. An occasional moth was seen in the trees adjacent to the lighted tree after dark. None were seen in trees further away from the light. Eggs were seen to be laid in all parts of the tree. These lights seem to be the most attractive to the moths and seem to increase the activity. I would say that the actions of the moths under these lights are not normal for at no other time, with lights or without, have I observed a swarming of ten or fifteen moths around a twig in direct light as I have seen them with the red lights."

Thus it appears that with the red bulbs great activity of the codling moth was stimulated but that it was largely, but not entirely, of an abnormal character.

The Mazda C lamp rays are distributed from 0.42 $\mu$ of the violet to 0.66 $\mu$ of the red, with an unusually heavy distribution in the red end of the spectrum. The Mazda CX shows a larger percentage of energy in the violet end of the spectrum. The Mercury vapor daylight lamp shows a distribution from the violet end of the spectrum, to the yellow, with a heavy delivery in the violet and ultra violet end of the spectrum. The red painted Mazda C's show a heavy emission of light in the red end of the spectrum with very little emission from the blue end of the spectrum. While the Mazda C light produced an appreciable reduction in infestation, it did not prevent egg laying in large numbers. The Mazda CX seemed to have about the same effect upon codling moth activity as the Mazda C. The mercury vapor daylight lamp seemed rather to stimulate the normal codling moth activity, while the red painted Mazda C seemed to stimulate the codling moth to an abnormal sort of activity.

Repeated studies of the time when the codling moth becomes active

under favorable temperatures show that moths begin to fly very promptly after the sunlight has fallen to 30 foot candles and that as the light decreases the activity becomes more pronounced until less than one foot candle prevails. Thereafter, the activity decreases to nothing when moonless darkness arrives.

The results of the experiments with the Mazda C lamps correspond in a general way to the results obtained by Herms (2) but clearly show that the amount of lighting necessary to the prevention of codling moth activity is much greater than was anticipated. The results with the Mazda CX do not differ from the Mazda C. The results with the mercury vapor daylight lamps are similar to those of Peterson (3) in that a lamp with the violet end of the spectrum prominent increases the normal codling moth activity. The results with the red light indicate that the red end of the spectrum is disturbing.

## Summary and Conclusions

The following conclusions seem justified:

1. The controlling factors in the effect of radio waves upon certain insects and certain plants seem to be frequency and current volume. The two are intimately combined but the frequency appears to furnish the selective agency and the current volume to provide the punch.

2. Soils develop heat when subjected to radio waves. The amount of heat developed is largely dependent upon the amount of water present. Dry soils heat slowly and wet soils heat rapidly.

3. Water under treatment with radio waves increases in heat slowly but definitely.

4. Irradiation of the foliage wall of the apple tree in the amount of 10 foot candles during first brood activity resulted in approximately 50% reduction in fruit injury by that insect.

5. Increasing the light energy delivered from the violet end of the spectrum seems to increase the normal oviposition activity of the codling moth.

6. Increasing the light energy delivered from the red end of the spectrum seems to induce largely abnormal activity, which is more or less aimless and not necessarily accompanied with oviposition.

7. Codling moth activity begins shortly after the sunlight has fallen to 30 foot candles.

8. In all probability an irradiation of a little more than 30 foot candles would be necessary during favorable evenings and mornings to prevent the codling moth from ovipositing.

REFERENCES

1. HEADLEE, T. J. The Differential Between the Effect of Radio Waves on Insects and on Plants. Journ. Econ. Ent., Vol. 24, No. 2, April, 1931, pp. 427–437.
2. HERMS, W. B. A Field Test of the Effect of Artificial Light on the Behavior of Codling Moth, *Carpocapsa pomonella* Linn. Journ. Econ. Ent., Vol. 22, No. 1, Feb., 1929, pp. 78–87.
3. PETERSON, ALVAH and HAEUSSLER, G. J. Response of the Oriental Peach Moth to Colored Lights. Annals Ent. Soc. of America, Vol. XXI, No. 3, Sept., 1928, pp. 353–379.

Doctor Baker asked if the soil flora had been studied. Doctor Headlee replied that the soils used were synthetic.

Hence, no studies of flora had been made. Mr. Hockenyos asked a question regarding the effect of the presence of salts in soils water on the development of heat in the soil. Doctor Headlee replied that so far as he has observed salts apparently retarded the development of heat. Further remarks by Professor O'Kane.

Mr. W. W. Stanley asked what there was in moonlight that made the codling moth fly. Doctor Headlee replied that he had not gone into that. A member asked if Doctor Headlee would discuss the paper which was to have been presented by Mr. Ginsburg. Doctor Headlee replied that the paper was in the hands of the Secretary of the Association.

# Proceedings of the Third Annual Paper-Reading Session of the Eastern Branch of the American Association of Economic Entomologists

## PART I. BUSINESS PROCEEDINGS

### First Business Session

*Thursday, November 19, 1931*

This meeting was held at the American Museum of Natural History, New York City, on November 19 and 20, 1931. The session was called to order by Chairman W. J. Schoene and welcomed by Dr. F. E. Lutz, whose remarks are included in Part II of the proceedings. Mr. A. F. Burgess brought greetings from President J. S. Houser who ,although unable to attend the sessions, extended his compliments and best wishes for a successful meeting. It was voted that Dr. F. E. Lutz, who expected to attend the sessions of the Entomological Society of Ontario the following day, convey to that society the greetings and best wishes of the Eastern Branch.

The following report of the Secretary-Treasurer was read and referred to the auditing committee.

#### Report of the Secretary-Treasurer

Membership in the Eastern Branch at the close of December 1930 amounted to 84 paying members. This membership was distributed as follows. For the purpose of comparison the paid membership at the close of November 1929 is given also.

| | End of November 1929 | End of November 1930 |
|---|---|---|
| West Virginia | 1 | 1 |
| Virginia | 5 | 4 |
| District of Columbia | 6 | 3 |
| Maryland | 5 | 6 |
| Delaware | 2 | 2 |
| Pennsylvania | 9 | 3 |
| New Jersey | 26 | 21 |
| New York | 27 | 28 |
| Connecticut | 10 | 9 |
| Rhode Island | 2 | 0 |
| Massachusetts | 6 | 5 |
| Vermont | 1 | 1 |
| New Hampshire | 0 | 0 |
| Maine | 0 | 1 |
| Canadian Provinces | 1 | 0 |
| Total | 101 | 84 |

Thirty-nine papers were presented at the November 1930 meeting, covering the following topics. As a matter of interest the distribution by topics of the 1929 proceedings is also included.

| | No. of Papers 1929 Meeting | No. of Papers 1930 Meeting |
|---|---|---|
| General | 2 | 3 |
| Equipment | 2 | 1 |
| Insects Injurious to Animals | 1 | 0 |
| Insects Injurious to Ornamentals | 2 | 5 |
| Diseases and Parasites of Insects | 3 | 2 |
| Insecticides | 6 | 10 |
| Bees | 2 | 0 |
| Oriental Fruit Moth | 6 | 3 |
| Japanese Beetle and Related Species | 5 | 6 |
| Mexican Bean Beetle | 2 | 1 |
| European Corn Borer | 1 | 1 |
| Insects Injurious to Fruit, Vegetable and Field Crops | 14 | 7 |
| Total | 46 | 39 |

Thirty-three papers were published in the February 1931 issue of the Journal of Economic Entomology occupying approximately 195 pages and nine plates. Nineteen text figures were included.

Under date of January 12, 1931, the committee appointed to present to the Executive Committee of the American Association of Economic Entomologists, at the Cleveland meetings, the proposals outlined in the report of the Publication Financing Committee, reported to Chairman W. J. Schoene that their proposals regarding the printing of papers offered at branch meetings had been accepted. The report of this committee follows:

"The undersigned committee was appointed by Chairman W. J. Schoene at the New York meeting held November 21, 1930, to submit to the Executive Committee of the Parent Association proposals for the publishing of papers presented at the Eastern Branch meetings. This special committee was instructed to negotiate with the Executive Committee and was given power to accept or reject for the Eastern Branch the proposals of the Executive Committee of the parent body. Accordingly, proposals for publication were submitted to the Executive Committee at its session held in Hotel Hollenden, Cleveland, Ohio, on December 29, 1930. The Executive Committee accepted the report and recommended that the publication proposals of our committee be accepted with the proviso that the provisions thereof be offered to all past, present or future branches of the society, and that these provisions would go into effect for any branch as soon as the branch informed the secretary of the parent society that it had accepted the same. The recommendations of the Executive Committee were offered and accepted by the parent association at the meeting held at Case School of Applied Sciences, Cleveland, Ohio, January 1, 1931.

"The undersigned committee accepts, on behalf of the Eastern Branch, the proposals regarding printing of papers offered at branch meetings as outlined in the report of the Executive Committee at Cleveland."

(Signed) C. H. HADLEY
F. Z. HARTZELL
J. L. KING

The following action was taken by the Executive Committee of the American Association of Economic Entomologists at the Cleveland meeting.

"The Executive Committee approves the proposal of the Eastern Branch that each officially recognized Branch of the parent Association be allowed the publication of 50 pages in the Journal of Economic Entomology, of its annual proceedings without

charge to the Branch; that the next 50 pages, or portion thereof, if any, be published by the Journal at a price of $1.50 per page, to be defrayed by the Branch; that matter in excess of 100 pages be published at a price of $3.00 per page, to be paid by the Branch concerned, provided that this arrangement shall be effective for each Branch as soon as it is officially approved by the Branch concerned."

FINANCIAL STATEMENT

*Cash Receipts*

| | | |
|---|---|---|
| Balance in bank November 17, 1930 | $329.07 | |
| Additional amount received for 1930 dues | 70.00 | |
| Amount received for 1931 dues to date | 132.00 | |
| Advance payments from two members covering 1932 | 4.00 | |
| Total receipts | | $535.07 |

*Cash Payments*

| | | |
|---|---|---|
| Postage | $ 15.95 | |
| Stationery | 3.40 | |
| Printing of November 1930 proceedings | 372.00 | |
| Refunded overpayment of dues | 4.00 | |
| Miscellaneous expenses (collection charges on Porto Rican check | .50 | |
| Total payments | | $395.85 |
| Balance on hand (deposited in Trenton Trust Company) | | $139.22 |

Respectfully submitted,

HARRY B. WEISS,
*Secretary-Treasurer*

November 19, 1931

The following report of the Publication Financing Committee was presented by Mr. Bromley and accepted.

REPORT OF THE PUBLICATION FINANCING COMMITTEE

This committee was selected to raise funds to aid in defraying the cost of publishing the Proceedings of the third annual meeting. The securing of additional funds became imperative as the amount realized from the 1930 dues was so small that sufficient funds were not available from the treasury.

It was decided to print the program for the meetings and sell advertising space in this program. One hundred and fifty dollars' worth of advertising space was sold in this program.

As it seems most desirable that the Eastern Branch be self-sustaining on the basis of membership dues, this Committee makes the following suggestions.

a. That only papers by members in good standing, i. e., those not in arrears in dues, be accepted for publication in the Journal as part of the Proceedings of the Eastern Branch meetings.

b. That papers be limited to six printed pages. For all papers submitted, the regular publication rules of the Journal should apply, i. e., that the cost of all matter in excess of six printed pages, a part page counting as a full page, this limit not including acceptable illustrations, be borne by the authors.

Respectfully submitted,

S. W. BROMLEY, *Chairman* J. R. STEAR
M. P. ZAPPE C. C. HAMILTON
ALFRED WEED *Committee*

The Secretary proposed Mr. W. W. Thomas, California Spray Chemical Company, 204 Franklin Street, New York, N. Y., and Mr. Oscar H. Hammer, Peru, N. Y., for affiliated membership, and they were duly elected.

Chairman W. J. Schoene appointed the following committees:

Auditing—F. Z. Hartzell, chairman, C. C. Hamilton and S. W. Bromley.

Nominations—E. N. Cory, chairman, R. D. Glasgow, and H. N. Worthley.

Resolutions—E. P. Felt, and W. E. Britton.

## Final Business Session

*Friday, November 20, 1931*

President W. J. Schoene called for the report of the nominating committee, which was adopted.

### Report of Committee on Nominations

For Chairman, L. M. Peairs.
For Vice-Chairman, Hugh Glasgow.

E. N. Cory
R. D. Glasgow
H. N. Worthley
*Committee*

The auditing committee reported that the report of the secretary-treasurer had been examined and found to be correct. Following this, it was voted that the report of the secretary-treasurer be accepted.

The chairman then called for the report of the committee on resolutions, which was adopted.

### Report of the Committee on Resolutions

Your committee recommends the adoption of the following resolutions:

***Resolved***, That the sincere thanks of the Eastern Branch of the American Association of Economic Entomologists be tendered the Director of the American Museum of Natural History and his associates for their kindness in furnishing quarters for these meetings and for the many other courtesies granted to members of our Branch at this, its third Annual Meeting, and further, that the Secretary be hereby instructed to send this resolution, together with a note of appreciation, to the governing body of the American Museum of Natural History.

***Resolved***, That this Branch express its sincere appreciation for the vigorous efforts of its special committee appointed to raise funds to meet part of the cost of publishing the Proceedings.

Whereas, In consideration of the very successful meetings of the Eastern Branch and the advantageous cooperative agreement effected for the publication of the Proceedings, therefore

*Be it Resolved*, That all entomologists in Eastern Branch territory be urged to support the organization by qualifying as members and thus enable us to attain a self-sustaining status.

Respectfully submitted,

E. P. FELT
W. E. BRITTON
*Committee*

After some discussion, during which it was apparent that many members preferred a regular meeting in November, 1932, the executive committee was authorized to select the time and place of the 1932 meeting.

On account of the crowded condition of the program it was necessary to section the meeting during the Friday afternoon session. Vice-chairman elect Glasgow took one section, and vice-chairman Garman, the other. At this time telegraphic greetings were received from the Entomological Society of Ontario, then in session at Guelph, Canada.

During the Friday afternoon session, Mr. George P. Engelhardt called attention to the publishing activities of the Brooklyn Entomological Society and in addition made the following remarks about the clear-wing moth, *Synanthedon corrusca*, as a potential enemy of the pecan industry of the south.

"The clear-wing moths, Family Aegeriidae, all borers in living plant tissues, are limited, with few exceptions to one or several closely related food plants. One of the outstanding exceptions is the so-called "woody oak gall borer—*Synanthedon scitula* Harris, of the East and its geographical race—*Synanthedon corrusca* Hy Edwards of the south.

"Feeding habits in this case appear to be controlled not by the specific attraction of any one plant, but rather by the physiological and pathological condition of a number of plants, disregarding relationship. Woody galls and swellings due to other insects, excrescences caused by fungus diseases, bruises and injuries in the process of healing are the favorite places of infestation.

"Breeding records for the Atlantic and midwestern states include oak, hickory, chestnut, dogwood, hazel, cherry, apple, willow; for the southern states, to be added beech, myrtle, loquat, pine and pecan. Long and well established as a borer in the crown galls and other malformations on pecan, both wild and cultivated, this insect is now developing adaptations as a bark and sapwood borer, which have resulted in serious injury to pecan groves in Baldwin County, Alabama.

"In view of the growing importance of the pecan industry in the

South, this observation is brought to the attention of the Eastern Branch."

The sessions were attended by approximately 129 entomologists. During the noon recesses of both days, Mr. C. H. Curran and Mr. A. J. Mutchler conducted groups on short tours through the Museum.

The following entomologists living in Eastern Branch territory are members. An asterisk preceding the names indicates registration at the 1931 meetings.

*H. W. Allen, Moorestown, New Jersey
*R. B. Arnold, Richmond, Virginia
*A. Edison Badertscher, Baltimore, Maryland
*Parker T. Barnes, Palmyra, New Jersey
*Kenneth A. Bartlett, Arlington, Massachusetts
*C. H. Batchelder, Melrose, Massachusetts
*Charles S. Beckwith, Pemberton, New Jersey
Avila Blanchard, Providence, Rhode Island
W. E. Blauvelt, Ithaca, New York
*W. E. Britton, New Haven, Connecticut
*Stanley W. Bromley, Stamford, Connecticut
*Raymond C. Brown, Melrose Highlands, Massachusetts
*Robert C. Burdette, New Brunswick, New Jersey
*A. F. Burgess, Greenfield, Massachusetts
*Emory D. Burgess, Lexington, Massachusetts
*F. Gray Butcher, Ithaca, New York
L. R. Cagle, Blacksburg, Virginia
F. L. Campbell, Takoma Park, Maryland
*Paul J. Chapman, Geneva, New York
*P. W. Claassen, Ithaca, New York
R. L. Clement, West Hempstead, New York
*C. W. Collins, Melrose Highlands, Massachusetts
Donald L. Collins, Cambridge, Massachusetts
*Ernest N. Cory, College Park, Maryland
Marcus S. Crane, Caldwell, New Jersey
*C. R. Crosby, Ithaca, New York
*S. S. Crossman, South Norwalk, Connecticut
Derrill M. Daniel, Geneva, New York
*W. M. Davidson, Silver Spring, Maryland
William T. Davis, Staten Island, New York
*L. P. Ditman, College Park, Maryland
*S. M. Dohanian, Somerville, Massachusetts
*Byrley F. Driggers, New Brunswick, New Jersey
E. H. Dusham, State College, Pennsylvania
*E. P. Felt, Stamford, Connecticut
*Robert S. Filmer, New Brunswick, New Jersey
*Henry Fox, Moorestown, New Jersey
*G. T. French, Richmond, Virginia
*Roger B. Friend, New Haven, Connecticut
*S. W. Frost, Arendtsville, Pennsylvania
*F. L. Gambrell, Geneva, New York
*Philip Garman, New Haven, Connecticut
*Joseph M. Ginsburg, New Brunswick, New Jersey
*Hugh Glasgow, Geneva, New York
*Robert D. Glasgow, Albany, New York
*C. Graham, College Park, Maryland
*D. H. Grant, Scotch Plains, New Jersey
C. C. Gwinner, Philadelphia, Pennsylvania
*C. H. Hadley, Moorestown, New Jersey
*Harold C. Hallock, Westbury, New York
*Clyde C. Hamilton, New Brunswick, New Jersey
*Oscar H. Hammer, Geneva, New York
*S. W. Harman, Geneva, New York
*Albert Hartzell, Yonkers, New York
*Frederick Z. Hartzell, Geneva, New York
*I. M. Hawley, Moorestown, New Jersey
*Thomas J. Headlee, New Brunswick, New Jersey
*G. E. R. Hervey, Geneva, New York
*L. L. Hill, Ithaca, New York
H. E. Hodgkiss, State College, Pennsylvania
*J. L. Horsfall, Yonkers, New York
*W. S. Hough, Winchester, Virginia

*H. C. Huckett, Riverhead, Long Island, New York
*J. Peter Johnson, Shelton, Connecticut
*M. P. Jones, Washington, D. C.
Thomas H. Jones, Melrose Highlands, Massachusetts
*J. L. King, Moorestown, New Jersey
*Josef N. Knull, Mont Alto, Pennsylvania
*George S. Langford, College Park, Maryland
*Mortimer D. Leonard, Rio Piedras, Porto Rico
*John C. Long, Lancaster, Pennsylvania
*G. F. MacLeod, Ithaca, New York
*J. A. Manter, Storrs, Connecticut
*Frank B. Maughan, Ithaca, New York
*H. S. McConnell, College Park, Maryland
*Donald McCreary, Newark, Delaware
*Frank L. McDonough, Middleport, New York
Henry L. McIntyre, Albany, New York
Warren Moore, New Brunswick, New Jersey
*William Moore, New York, New York
F. G. Mundinger, Poughkeepsie, New York
*Franklin C. Nelson, Roselle, New Jersey
Howard Notman, Dougan Hills, New York
*W. C. O'Kane, Durham, New Hampshire
*P. J. Parrott, Geneva, New York
L. M. Pears, Morgantown, W. Va.
*E. F. Phillips, Ithaca, New York
*C. R. Phipps, Orono, Maine
*F. W. Poos, Washington, D. C.
*W. A. Rawlins, Ithaca, New York
*T. W. Reed, Geneva, New York
I. L. Ressler, Niagara Falls, New York
*Henry H. Richardson, Washington, D. C.
E. Avery Richmond, Brockton, Massachusetts
*R. C. Roark, Washington, D. C.
*John A. Rodda, Baltimore, Maryland
*S. A. Rohwer, Washington, D. C.
*V. I. Safro, New York, New York
J. G. Sanders, Philadelphia, Pennsylvania
*W. J. Schoene, Blacksburg, Virginia
*John C. Schread, New Haven, Connecticut
R. W. Sherman, South Norwalk, Connecticut
*G. W. Simpson, Orono, Maine
*Floyd F. Smith, Washington, D. C.
George A. Smith, Boston, Massachusetts
*F. J. Spruijt, Babylon, Long Island, New York
*J. R. Stear, Ligonier, Pennsylvania
L. A. Stearns, Newark, Delaware
Phillis W. Stockwell, Norwalk, Connecticut
Harvey L. Sweetman, Amherst, Massachusetts
*C. A. Thomas, Kennett Square, Pennsylvania
*W. W. Thomas, New York, New York
F. M. Thompson, Jr., New Brunswick, New Jersey
*Neely Turner, New Haven, Connecticut
*G. W. Underhill, Blacksburg, Virginia
*B. D. Van Buren, Albany, New York
*Arlo M. Vance, Arlington, Massachusetts
E. R. Van Leeuwen, Moorestown, New Jersey
*Joseph S. Wade, Washington, D. C.
*B. H. Walden, New Haven, Connecticut
*Charles A. Weigel, Washington, D. C.
*Harry B. Weiss, New Brunswick, New Jersey
W. D. Whitcomb, Waltham, Massachusetts
C. R. Willey, Richmond, Virginia
*L. L. Williams, Newark, Delaware
D. O. Wolfenbarger, Ithaca, New York
*Henry T. Wood, Kingston, New York
*A. W. Woodrow, Ithaca, New York
*H. N. Worthley, State College, Pennsylvania
*L. H. Worthley, Norwalk, Connecticut
*M. P. Zappe, New Haven, Connecticut

The following guests also were present at the meetings:

W. L. Baker, Melrose, Massachusetts
F. S. Blanton, Babylon, Long Island, New York
F. H. Butt, Ithaca, New York
D. J. Caffrey, Toledo, Ohio
C. H. Curran, New York, New York
H. W. Dye, Middleport, New York
P. M. Eastman, Albany, New York
G. P. Englehardt, Hartsdale, New York
David E. Fink, Takoma Park, Maryland
Walter E. Fleming, Moorestown, New Jersey
S. B. Fracker, Washington, D. C.
John Gray, Moorestown, New Jersey
R. W. Harned, Washington, D. C.
A. S. Hoyt, Washington, D. C.
D. M. Hickcox, Port Chester, New York

W. J. Holland, Pittsburgh, Pennsylvania
J. A. Hyslop, Washington, D. C.
Howard A. Jones, Washington, D. C.
B. H. Little, Wilmington, Delaware
F. E. Lutz, Ramsey, New Jersey
A. J. Mutchler, New York, New York
Chris E. Olsen, New York, New York
S. F. Potts, Melrose, Massachusetts
George E. Smith, Albion, New York
A. E. Stene, Kingston, Rhode Island
Lee A. Strong, Washington, D. C.
H. H. Thornberry, Yonkers, New York
Alfred Weed, New York, New York
McLaughlin Gormley King Company, Minneapolis, Minnesota

HARRY B. WEISS
*Secretary-Treasurer,*

## PART II. PAPERS

### "WELCOME"

A revised edition of the old saying has it that "The proof of the pudding is whether the guests ask for second helpings." If they do, the cook is pleased. Applying that saying to the present occasion, the American Museum in general and its entomological department in particular is delighted that you have seen fit to let us be your host once again. We assure you that there is plenty of pudding in the kitchen.

I am very sorry that my wandering habits prevent me from waiting on the table but you have Mutchler, Curran, Schwarz, Watson, Wunder and others. Please tip them. That is, please tip them off if there is anything which you want and which is not brought to you before you ask.

On the bill of fare are several new buildings and the being-revised Hall of Insect Life. Please notice that we call it the Hall of Insect *Life* and not merely the Insect Hall. Partly because we wish to make our exhibits more than static, dead things, we have experimented in a crude way with the display of living insects. The experiment has been such a success that we are now building right in the center of the hall a small insect zoo.

Another exhibit which is in the course of preparation shows some of the more than a thousand different kinds of insects actually collected in a 75 x 200 ft. lot in the heart of a suburban town.

In this hall we are giving an outline of the injury done by the few really injurious insects but we dislike hearing the villainy of these few shouted from the house-tops with nothing, or almost nothing, said about the good we get from thousands of others. Accordingly, we show "Some of the Things we Owe to Insects" and the particular exhibit to which I refer does not include parasitic insects.

You may be interested in the research side of our department. On the table is a somewhat complete set of our publications. They cover a period of about 40 years. During the last fifteen of these years we have

averaged approximately 350 pages per year, a fairly sizeable entomological journal although not bearing a title as such. In fact, and quite out of proportion to the department's budget, 28% of the American Museum's entire scientific publication is entomological.

In our scentific collections we are hampered by the smallness of our staff. Such being the case and to avoid duplication of effort, we are stressing work on groups which are not especially the province of institutions of applied entomology such as the National Museum. This does not mean that we are not glad to receive and to take good care of named specimens of such distinctly economically important insects as scale insects, plant lice, and parasitic wasps, but please let them come with their names on them.

Speaking of the care of insects, may we call your attention to our collection of types. If we have the type of a species, that fact is noted on a conspicuous label in the general collection but the type itself is locked up in a fire-proof, doubly dermestid-proof case, all the types of a given author being kept together under his name.

The troublesome question of loaning types has been compromised as follows. We will loan types provided we have the written consent of the person who deposited them here. If that person is dead and had left no such written consent, it is just too bad for the would-be borrower. However, if a person who trusts us with the safe-keeping of his types wishes them to be loaned to responsible people after his death, he may give us a note to that effect and we will pin that note in the drawer with his types for the guidance of us and of our successors until time shall be no more.

Meanwhile, we hope that you will have a pleasant and profitable meeting here this week and that you will come again. Please consider the American Museum to be your home now and as long as we both are.

FRANK E. LUTZ.

## THE INITIATION OF AN INSECT PEST SURVEY IN PORTO RICO

By M. D. LEONARD, *Rio Piedras, Porto Rico*

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# INSECTICIDES ON SHADE TREES AND ORNAMENTALS

By E. P. FELT and S. W. BROMLEY, *Bartlett Tree Research Laboratories, Stamford, Connecticut*

ABSTRACT

A series of tests were conducted to determine tolerance of various trees and shrubs to dormant oil sprays. At Stamford, Connecticut, the sugar maple, black walnut, butternut and beech were found to be very susceptible to oil injury, and certain conifers, particularly the spruces, were apt to be injured where excessive amounts were used. The other trees and shrubs sprayed with various oils at dormant strength were not injured by the application.

Dormant oil 1–16 was very effective in killing the overwintering young of the tulip tree scale, *Toumeyella liriodendri*. The white pine bark aphid, *Adelges pinicorticis*, was very satisfactorily controlled with a dormant oil at 1–25, 1–50 and 1–50 to which was added nicotine sulfate (40%) 1–800. Tests of several commercial sprays applied to spruce branches and the latter then immediately covered with paraffin bags resulted in no appreciable injury, indicating that high humidity was probably not an important factor in causing injury.

A lead oleate, coated arsenate of lead applied to twigs upon which feeding hickory bark beetles, *Scolytus quadrispinosus*, were confined resulted in appreciably more killing than in the case of others sprayed with ordinary arsenate of lead. A spray of 2% summer oil plus nicotine sulfate 1–800 and a commercial vegetable oil, soap, nicotine sulfate mixture diluted 1–10 gave practically 100% kill of young juniper scale, *Diaspis carueli*, in midsummer. A very satisfactory control, 95–100%, was secured in the case of a number of insects by spraying with the vegetable oil, soap, nicotine spray.

There is probably no phase of insecticide application where the problems of insect control and spray tolerance of trees, shrubs and plants are more complex than in the field of shade trees and ornamentals. The great variety of trees and shrubs encountered, each with its specific insect pests and specific tolerance to sprays, presents an array which is unparalleled in orchard or other crop spraying. We do not mention Forestry, as here the use of insecticides is comparatively limited. But, in shade tree work, it is imperative that the insecticide be quickly acting, effective, and well within the limits of safety to the plant.

We may roughly classify insecticides for shade tree and ornamental use into two groups, according to the time of application, as (I) Dormant applications, and (II) Foliage applications.

I. DORMANT APPLICATIONS. Effective sprays during the dormant season are very desirable as at this time an infestation may be destroyed before the growing season, thus obviating insect damage which might otherwise become established before it could be checked by subsequent measures and thus may be termed preventive spraying, an insurance against attack rather than a palliative.

Dormant sprays in general are directed against insect eggs or overwintering stages of such haustellate insects as scale insects or aphids. Oil sprays are given preference in shade tree work, as lime sulfur cannot be used in the vicinity of buildings, due to its deleterious action on painted surfaces.

Some trees are susceptible to injury from oil applications even under dormant conditions, and this is a complicating factor, the limits of which must be explored by most careful and extensive experimentation dealing with a great variety of trees, under many varying conditions, and a great variety of types of oils.

Some of the more important factors influencing oil injury are:

1. The quantity of oil applied to the tree.
2. The species of tree.
3. The type of oil.
4. The temperature and weather conditions during and following the time of application.
5. The condition of the tree at the time of spraying.

The quantity of oil applied to the tree is no doubt one of the most important factors affecting the possibility of injury. Excessive applications may result in injury where a normal application would be safe. For instance, one of the standard makes of dormant oils will in many cases kill a sugar maple at a strength of 1–16, but at 1–50 will cause little or no injury.

Certain trees are now known to be much more susceptible to injury than others. Under the conditions of experiments conducted at Stamford, Connecticut, sugar maple, black walnut, butternut, and beech were found to be very susceptible to oil injury, and certain conifers, particularly the spruces, were apt to be injured where excessive amounts were used. The use of dormant oils on Japanese maple is also known to be attended with danger.

The type of oil used is very important also, but fortunately great advances have been made by the manufacturers in standardizing the types of oil during the past decade and variation, which might result in serious injury to species of trees which would ordinarily be immune, is largely a thing of the past.

Unfavorable weather conditions for oil sprays are fairly well known and can be avoided. Freezing conditions are, of course, definitely harmful and a general rule is not to apply dormant oils when the temperature is below 40° F. High temperatures are also dangerous, particularly for

conifers or trees which are naturally cold climate trees and are planted out of their normal range. For instance, Norway spruce in New England may be sprayed with comparative impunity with a strength of delayed dormant oil which a hundred and fifty or two hundred miles further south might produce serious injury.

The condition of the tree at the time of spraying is an important factor. Many tests have indicated that certain trees at least are more susceptible to oil injury when sprayed in the fall than when sprayed in the spring.

A series of tests involving the dormant spraying of 343 trees, comprising 32 different species, were conducted during the fall of 1930 and the spring of 1931. Five well known makes of dormant oil sprays were compared in these tests.

No oil injury resulted from the application of any of the makes used at the normal dilution of 1–16, either in the spring or in the fall, in the case of any of the following: Pin Oak (44 trees sprayed); Red Oak (6 trees sprayed); Gray Birch (7 trees sprayed); Red Pine (7 trees sprayed); White Ash (10 trees sprayed; bud development slightly delayed in one case); Scarlet Oak (1 tree sprayed; spring application); Box (3 shrubs sprayed); Catalpa (3 trees sprayed); American Elm (7 trees sprayed); Red Maple (5 trees sprayed); White Pine (5 trees sprayed); Sweet Cherry (8 trees sprayed); Pear (10 trees sprayed); Sour Cherry (14 trees sprayed); White Oak (9 trees sprayed); Tulip Tree (2 trees sprayed); Large-tooth Poplar (5 trees sprayed); Black Oak (23 trees sprayed); Norway Maple (3 trees sprayed); Silver Maple (3 trees sprayed); and European Linden (5 trees sprayed).

One sugar maple sprayed on December 4, 1930 showed a few live branches on May 16th, 1931, but the tree was completely dead on May 28th. Three young trees sprayed in the spring (April 4, 1931) with a dilution of 1–50 were uninjured. Of two American Beeches sprayed in the fall, one was greatly retarded and the other was killed. Of seven trees sprayed in the spring with the same strengths, none were seriously injured although all showed enlarged bark lenticels and one showed a few dying branches. Of seven shagbark hickories sprayed in the fall, three were uninjured, three greatly retarded and the top of one was killed. Of six sprayed in the spring, 5 were uninjured and one was retarded. In the case of Black Walnuts, individual branches on five different trees were sprayed, the applications being made in the spring. Of these, one was uninjured, two slightly retarded, and two severely injured. Of three

butternut trees sprayed, one in the fall and two in the spring, all were rather seriously injured. Of four yellow birch sprayed, three were uninjured and one was slightly retarded. Of six flowering dogwood sprayed, five were unaffected and one was slightly retarded. Lilac was uninjured by spring applications, as were apple trees. Of spring applications to five peach trees, none were definitely injured, although all were apparently slightly retarded. Of eleven red cedars sprayed, six were uninjured, while considerable browning developed on the foliage of seven.

Most of the well recognized brands of dormant oils at 1–16 are very effective in killing the overwintering young of the tulip tree scale. A test was conducted on April 20, 1931 to determine the effectiveness of a spray in which the amount of oil used was lessened, but to which was added nicotine sulfate. A mixture of a dormant oil 1–50 and nicotine sulfate (40%) 1–800 was applied to a small tulip badly infested with the overwintering young of the tulip tree scale, *Toumeyella liriodendri* (Gmel.). The tree was still dormant. Weather conditions were clear, sunny, with a light breeze. Temperature 69° F. and relative humidity 43%. An examination on May 26, showed a kill of only 81.7% of the scale. This and other tests have emphasized the advisability of using the full strength of oil for the control of this insect in the dormant condition.

The following experiment was conducted to determine what might be expected in the way of control of the white pine bark aphid, *Adelges pinicorticis* (Fitch) from the application of oil sprays to the woolly egg masses affixed to the bark of trees. Three rather uniformly infested white pines, about 30 feet in height, were sprayed on April 20, 1931 with a dormant oil, one at 1–25, one at 1–50 and one at 1–50 to which was added nicotine sulfate (40%) 1–800. The applications were begun at 2:00 P. M., the weather conditions sunny, calm to a light southwest breeze, temperature 72° F. to 69° F. and relative humidity 73% to 72%. An examination on May 25th failed to reveal any living eggs on the lower portions of any of the sprayed trees, while on unsprayed trees next in the row, most of the eggs were alive and some young were hatching. No spray injury resulted.

It has been suggested that in the case of certain conifers, oil injury might be brought about by conditions of high humidity. An experiment to throw light on this point was conducted on May 25, 1931. A series of small branches on the shaded portion of a Colorado blue spruce were

sprayed with the following: Light Volck 1–50; Sunoco 1–50; Scalecide 1–50 and Wilson's O. K. 1–10. Two branches were sprayed with each, one of which was covered with a paraffined paper bag and the other left uncovered. The enclosed branches were first shaken before covering to remove excess spray. The purpose of the paraffined bag was to subject that particular branch to a high relative humidity. The buds were just beginning to break. The applications were made between 3:45 P. M. and 4:30 P. M. Weather conditions were partly sunny and cloudy, calm; temperature 64° F. and relative humidity 74%. These branches were examined from time to time, the bags being removed on May 29th. No injury, other than removal of the "bloom" resulted on either the exposed twigs or those enclosed.

II. Foliage Applications. The insecticides used for foliage applications, which possess to the greatest degree that property of protection against insect attack ascribed to the dormant sprays, are the arsenicals, which, of course, are effective only against chewing insects, and only so long as they persist on the foliage. For protecting a tree or shrub from the attack of chewing insects, the physical properties of the spray are very important. Here our object is to coat the leaf with a film of poison as completely as possible and for as long a time as possible. Calcium caseinate, certain glues, lead monoxide and certain oils have been used with arsenate of lead to increase adherence or bring about better spreading.

It was discovered at the Japanese Beetle Laboratory that the use of a lead oleate coated arsenate of lead resulted in a much higher percent kill of the Japanese beetle than where ordinary arsenate of lead was used. That this may be true where other beetles are concerned, was indicated by certain experiments with the hickory bark beetle, *Scolytus quadrispinosus* (Say) during the past season.

A number of adults of this species were reared from infested hickory branches. Twenty-six active adults which had not fed were placed in each glass jar together with fresh twigs of hickory on July 21, 1931. In one case, the hickory twig had been sprayed with arsenate of lead paste at the rate of 12 lbs. to 100 gallons plus calcium caseinate at the rate of 2 lbs. to 100 gallons; the second twig had been sprayed with coated arsenate of lead, 10 lbs. to 100 gallons; and the third was left unsprayed as a check. The spray had been allowed to dry before introduction of the twig into the jars. The beetles in the check began to feed at the bases of the buds immediately. On the sprayed twigs, they

fed at first only at the cut ends of the shoots which were free from spray. On July 23, after approximately 48 hours, the check showed 15.3% of the beetles dead and feeding at the base of all four buds on the hickory shoot; the jar containing the twig sprayed with arsenate of lead plus calcium caseinate showed 39.1% of the beetles dead, and feeding at the base of all four buds, but only about half as much frass removed as in the case of the check; while the jar containing the twig sprayed with coated arsenate of lead showed 56% of the beetles dead and feeding at the base of only three of the five buds on the shoot.

There are many contact sprays which are effective in killing such sucking insects as aphids, provided actual and thorough contact is made. In this field also, the physical properties of the sprays, the method and time of application and the type of equipment are of almost equal importance to their intrinsic insecticidal value. A spray in the laboratory which may give a 100% kill of a certain insect may fail in actual field practice, due possibly to some physical property of the spray itself, possibly to the type of growth of the plant, shrub, or tree which militates against thorough contact, or to the position on the plant of the insects themselves. In many cases, certain insects attack only the undersides of the foliage and demand the use of a type of spray equipment which will insure their being hit by the spray. For the contact insecticide, wetting power is paramount. The speed of wetting is also an important factor, particularly in the case of insects which are more or less active.

For such exposed insects as most leaf hoppers and aphids, a soap-nicotine or a safe vegetable-oil soap-nicotine or a pyrethrum soap spray are all effective and safe. For more resistant sedentary species, such as the partly grown young of scale insects or for red mites, certain of the light mineral oils used with nicotine are particularly well adapted.

A comparative field test was conducted with a two per cent summer oil plus nicotine sulfate 1–800 and a commercial vegetable-oil soap, nicotine sulfate mixture which was diluted 1–10, on the young of the juniper scale, *Diaspis carueli,* (Targ.) and one-third grown. The applications were made at 10:00 A. M. on August 8, 1931 with weather conditions partly cloudy and sunny, a light breeze, temperature 72° F. and relative humidity 69%. A final check on November 5th showed that a natural mortality of 17.8% had occurred on the unsprayed; a mortality of 98.9% where the two per cent summer oil nicotine spray was used and a mortality of 92.2% where the vegetable-oil, soap, nicotine spray had been used.

A rather extensive test employing the same vegetable-oil, soap, nicotine spray, which has met with great favor because of its safety and effectiveness, was conducted on June 29, 1931. Application was made by means of an Arlington Power Sprayer between 1:15 and 4:15 P. M. Weather conditions were clear, light breeze, temperature 79° F–83° F; relative humidity 46%–45½%. Dilution 1–15. Excellent wetting was obtained in all cases and no injury resulted. This effectiveness is tabulated as follows:

| | Tree or Shrub | Insect Pest | Per cent Control Estimated July 1, 1931 |
|---|---|---|---|
| 1. | Almond | European red mite *Paratetranychus pilosus* (C. & F.) | 92 |
| 2a. | Plum | Mealy plum louse *Hyalopterus arundinis* (Fab.) | 100 |
| b. | Plum | Mealy plum louse | 100 |
| c. | Plum | Mealy plum louse | 95 |
| 3. | Malus purpurea | Green apple aphid *Aphis pomi* (DeG.) | 90 |
| 4. | Malus spectabilis | Green apple aphid | 99 |
| 5. | Malus coronaria | Green apple aphid | 99 |
| 6. | Tulip tree | Leaf aphid *Microsiphum liriodendri* (Monell) | 99 |
| 7. | Red pine | Aphid *Dilachnus* sp. | 100 |
| 8. | Spirea | Spirea aphid *Aphis spiraecola* (Patch) | 100 |
| 9E. | Red cedar | Immature spittle insects *Cercopidae* | Practically 100 Spittle dried up |
| W. | Red cedar | Immature spittle insects | Practically 100 Spittle dried up |
| 10. | Phlox | Garden red mite *Tetranychus telarius* (Linné) | 95 on outer leaves Most alive on inner leaves |
| 11. | Golden glow | Red aphid *Microsiphum rudbeckiae* (Fitch) | 100 |

## SPRAYING AND DUSTING EXPERIMENTS FOR THE CONTROL OF LEAFHOPPERS INFESTING DAHLIAS AND ASTERS[1]

By CLYDE C. HAMILTON, Ph.D., *Associate Entomologist, New Jersey Agricultural Experiment Station*

ABSTRACT

Tests during the summer of 1930 with pyrethrum sprays and dusts, nicotine sprays and dusts, white oil sprays of four viscosities, these same four white oils impregnated with copper oleate, a sulfonated oxidized oil and Bordeaux sprays showed that all the sprays were effective in killing leafhoppers on asters and dahlias except the Bordeaux sprays, that the Bordeaux sprays and the pyrethrum dusts were the

[1]Paper of the Journal Series, New Jersey Agricultural Experiment Station, Department of Entomology.

only materials tested which acted as repellents to the leafhoppers, and that all the sprays were safe upon the plants with repeated applications except the white oil sprays which, when used alone and impregnated with copper oleate, caused burning to the foliage of asters.

Tests conducted during the summer of 1931 with pyrethrum sprays and dusts and Bordeaux sprays showed that heavy applications of Bordeaux sprays or of a pyrethrum dust applied dry or as a wet wash were effective in repelling the green apple leafhopper (*Empoasca mali*) for a period of four to five days. Nicotine dusts were of only slight value in repelling the leafhoppers. Six foot cheesecloth cages constructed around groups of plants supplemented with an occasional dusting with pyrethrum gave the best control of leafhoppers. The leafhopper population in the treated plots was reduced to zero at each treatment but was built up almost to that of check plots within five days due to migration of the leafhoppers from outside sources.

The Control of Insects infesting many of our flowers presents a problem which has not been satisfactorily solved. Most of these insects are species normally infesting weeds or cultivated crops which migrate to flowers after their usual food plants have become less succulent. Many species continue to breed on the weeds or other plants surrounding the flower garden and migrate onto the flowers thruout the summer. This is particularly true of the various species of leafhoppers and sucking plant bugs infesting flowers. Thus we have the problem of not only finding a material which will kill the insects but also of finding one which will prevent their reinfestation of the plants.

Work on the control of the insects and especially leafhoppers infesting dahlias and asters was started the spring of 1930. A number of different spray and dust materials were tested to determine their effect upon killing the insects, preventing their reinfesting the plants and their effects upon the plants. These materials included nicotine sprays and dusts, pyrethrum sprays and dusts, white oil sprays of four different viscosities and these same white oils impregnated with copper oleate, a sulfonated oxidized oil and Bordeaux spray. A total of 8 applications were made over a period of 57 days. All of the sprays and dusts were effective, when properly applied, in killing leafhoppers except the Bordeaux spray, they were all safe on the plant foliage at the strengths applied except the oil sprays which caused a slight amount of leaf burning when used alone and considerably more burning when impregnated with copper oleate. Heavy applications of Bordeaux spray and thorough dustings with pyrethrum dusts were effective in preventing or retarding reinfestation of leafhoppers for several days. The details of this work are given in the annual report of the Department of Entomology for 1930–1931.

The tests conducted in the summer of 1930 indicated that the best results could be expected with pyrethrum dusts and Bordeaux sprays, therefore, more attention was given to these materials in 1931.

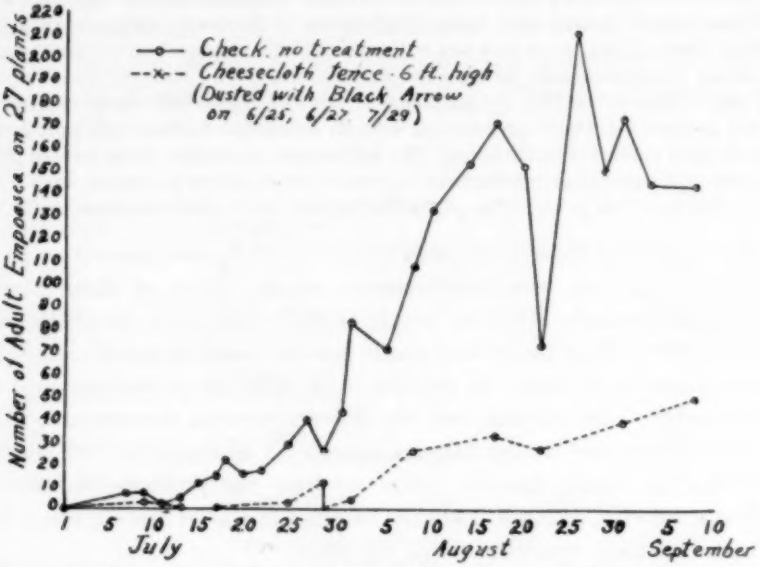


FIG. 19.—Population of Empoasca on Dahlias, Check Plot and Inclosure. Summer of 1931.

Approximately 300 annual aster plants of mixed colors and 300 dahlia plants of the varieties Mrs. Warner, Avalon and Harry Mayer, were set out in early June. From 16 to 32 plants were used in each test block. The first treatments were made on June 22nd and continued at from 4 to 5 day intervals until August 14th. Counts were made at intervals of 1 to 5 days after treatment to determine the number of leafhoppers found on the plants in each of the treated blocks. The aster leafhopper, (*Cicadula sexnotata* Fallen) on asters and the green apple leafhopper, *Empoasca mali* LeB., on dahlias were the most common species and were the ones on which counts were made.

The tabular data are rather extensive and since they will be published elsewhere later, they are not given here. The materials tested are as follows: "Red Arrow" diluted 1 to 300 and 1 to 600 with water, a dry commercial Bordeaux used at strengths equivalent to a 4–4–50 and a 8–8–50 formula plus 1% powdered skim milk in the diluted spray, a pyrethrum dust (Black Arrow Insect Dust) used as a dust and

also as a thin wash equal to 1 part by weight to 25 parts of water. In addition, approximately 90 aster plants and 30 dahlia plants were enclosed in each of two cheese cloth cages 6 feet high. The aster plants

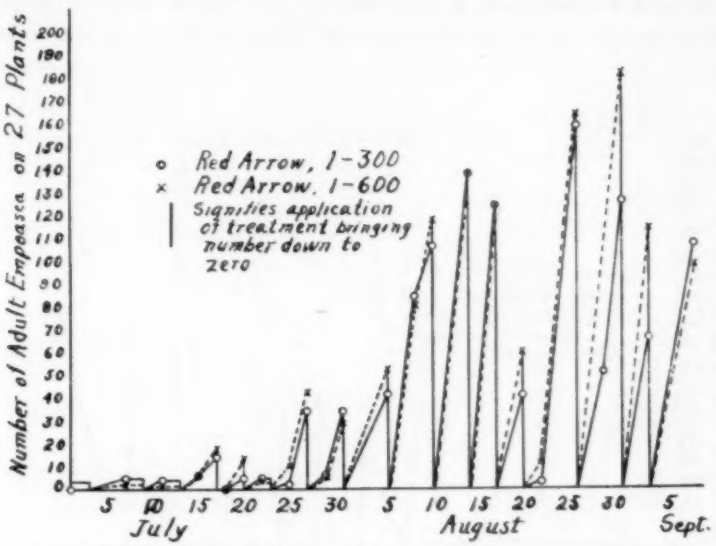


FIG. 20.—Population of Empoasca on Dahlias, Summer of 1931.

in the enclosure were dusted with Black Arrow Insect Dust on June 22nd, 24th and 26th and again on July 17th and the dahlia plants were dusted with Black Arrow Insect Dust on June 25th, 27th and July 29th.

The gray aster leafhoppers were scarce on the aster plants and the total numbers found on the plants in each treated block for the season and the percent of plants showing aster yellows are as follows: Red Arrow 1–300, 34 leafhoppers, 12.5% yellows; Red Arrow 1–600, 40 leafhoppers and 12.5% yellows; Bordeaux 4–4–50 formula, 15 leafhoppers, and 25% yellows; Bordeaux 8–8–50 formula, 13 leafhoppers and 18.7% yellows; Black Arrow Insect Dust in water 13 leafhoppers and 31% yellows; Black Arrow Insect Dust, 25 leafhoppers and 27.4% yellows; cheese cloth enclosure 8 leafhoppers and 4.4% yellows and check 52 leafhoppers and 18.8% yellows. The total number of leafhoppers found during the season and the number of plants used in the plots are rather small to draw a definite conclusion. They indicate, however, the superiority of the cheese cloth cage in reducing the number of leafhoppers and keeping down the aster yellows. No pulling out of plants infested with aster yellows was practiced.

The leafhoppers on the dahlia plants were considerably more numerous and were continually migrating onto these plants from apple trees and other dahlia plants adjacent to the test blocks. The data obtained represent a considerable larger number of insects and is, therefore correspondingly more representative of the true value of the materials tested.

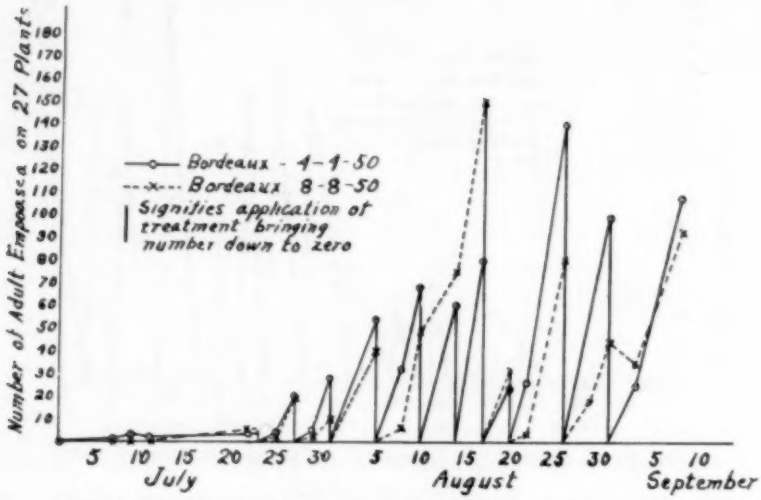


FIG. 21.—Population of Empoasca on Dahlias. Summer of 1931.

The leafhopper population on the dahlia plants increased considerably from the first of July to the last of August. About the first of September the numbers began to decrease. Figure 19 shows the number of adult *Empoasca mali* at various dates throughout the season on 27 plants in the check block and on an equal number of plants in the six foot cheese cloth enclosure. In addition to the adult leafhoppers many nymphs were found, but not counted, on the check plants and a few nymphs on the plants in the cheese cloth enclosure. Figures 20, 21 and 22 show the leafhopper population on the plants in the treated plots. Leafhopper counts were made just before treatment and soon afterwards. The observations made after treatment showed a total absence of living leafhoppers. This was not true for plants in the dahlia trial gardens which were adjacent and which were dusted regularly twice a week with a nicotine dust. The nicotine dust was applied by laborers and was not as thoroughly done as the test plots.

These data show that the Black Arrow Insect Dust was considerably

better than the Red Arrow pyrethrum spray in preventing reinfestation by leafhoppers and about of the same value as the Bordeaux sprays. The heavier application of Red Arrow spray and of Bordeaux as well as the wet application of the Black Arrow Insect Dust were of the most value.

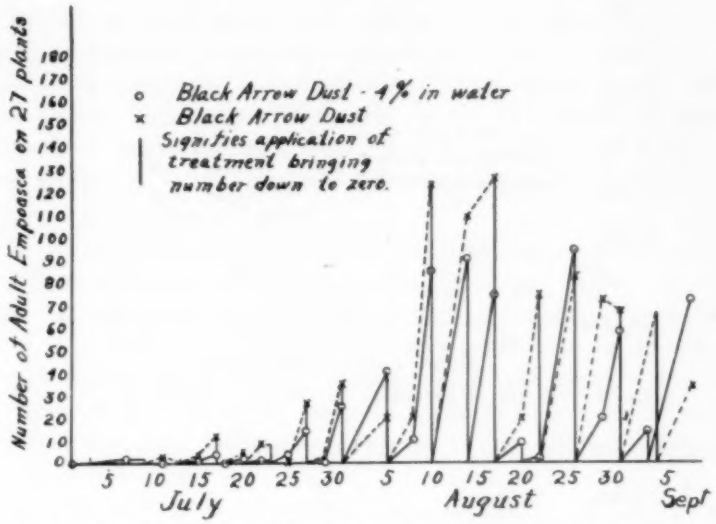


FIG. 22.—Population of Empoasca on Dahlias, Summer of 1931.

Figures 23 and 24 show the per cents control one, two, three, four and five days after treatment in repelling the leafhopper from the treated block. This percent repellency is based upon the numbers found in the check plot being used as 100 per cent infestation. All of the test plots gave approximately 100 per cent control 24 hours after treatment and from 70 to 95% control 48 hours after treatment. The effects of the materials began to disappear rapidly after 3 and 4 days. The Bordeaux spray and the Black Arrow Insect Dust used as a wash were distinctly better than the Red Arrow Spray and slightly better than the Black Arrow Insect Dust. Black Arrow Insect Dust as a thin wash was easier applied to the under surface of the foliage and remained longer.

Dusting tests with pyrethrum dusts on asters and dahlias at five different places in the state which were carried on coöperatively with growers gave very satisfactory results in preventing leafhopper damage or in very materally reducing the leafhopper population on the plants.

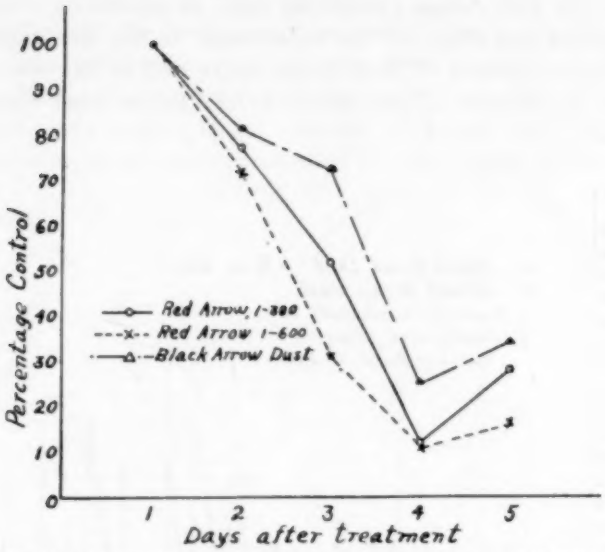


FIG. 23.—Control of Empoasca on Dahlias, Summer of 1931.

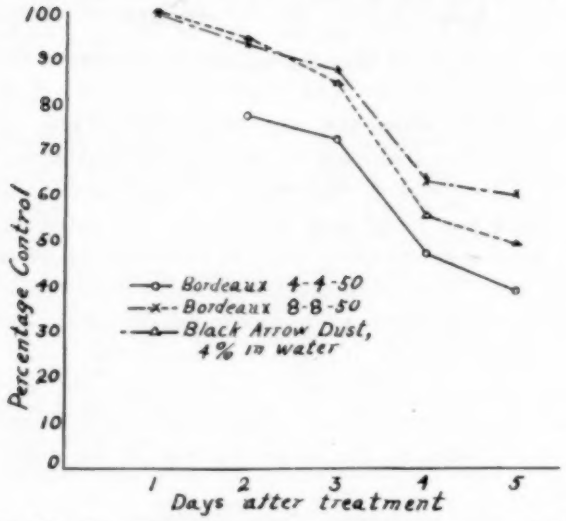


FIG. 24.—Control of Empoasca on Dahlias, Summer of 1931.

SUMMARY AND RECOMMENDATIONS. The tests with various spray and dust materials showed that all of them containing a contact insecticide were satisfactory in killing leafhoppers on dahlias and asters, if thoroughly applied.

Repeated applications of white oil sprays resulted in a slight amount of burning to aster foliage but caused no burning to dahlia foliage. The other materials caused no injury to the foliage.

Bordeaux spray, and pyrethrum dusts had a rather distinct repelling effect against leafhoppers for several days. This repellency gradually disappeared by the fourth or fifth day. Pyrethrum soap sprays had a slight repellency, while nicotine sprays and nicotine dusts appeared to have very little repelling effect.

The use of 6 foot cheese cloth cages surrounding the asters or dahlias, supplemented with several dustings of a pyrethrum dust at the time the plants were enclosed and one dusting later in the season gave the best results in reducing the number of leafhoppers found on the plants.

Observations and counts of numbers of leafhoppers on the treated plots showed no breeding as indicated by leafhopper nymphs and indicated that the adult leafhoppers were migrating into the treated plots from outside sources.

It is believed that enclosing the asters or dahlias in a 6 foot cheese cloth fence at the time the plants are set out and supplementing this with an application of a dust or spray material about every two weeks will prevent injury by leafhoppers to the plants. If it is not practical to construct a cheese cloth cage, heavy applications of a 4–4–50, or stronger Bourdeaux spray or of a Pyrethrum dust applied as a dust or a wet spray will give good results in preventing leafhopper injury. These applications should begin as soon as the plants are set out, should be applied at intervals of not more than 4 or 5 days and should continue until the plants begin to form buds, or later if some deposit on the foliage is not objectionable.

Aster plants showing yellows should be pulled up and destroyed as soon as the disease is noticed.

# TAENIOTHRIPS GLADIOLI M. & S.,[1] A NEW PEST OF GLADIOLUS

By FLOYD F. SMITH and C. A. WEIGEL,* *Bureau of Entomology, United States Department of Agriculture*

ABSTRACT

This paper consists of a description of the injury to gladiolus caused by a recently described species of thrips, *Taeniothrips gladioli* M. & S. Information concerning its distribution, notes on the life history and habits of the several stages of this thrips, and suggestions for its control are given.

During the season 1931, the Bureau of Entomology received numerous inquiries concerning serious injury by thrips to flowers of gladiolus. As the season progressed the inquiries became more frequent and the reports indicated that the losses were reaching such proportions that an immediate survey of the situation was necessary. In late August Floyd F. Smith visited the Rochester and Buffalo, N. Y., areas because it appeared from the information received that the gladiolus in this region was more generally affected. After examining a few of the infested fields it was evident that the reports were not exaggerated, because the thrips had virtually ruined the crop of flowers.

While four species of thrips, viz., *Taeniothrips gladioli* M. & S.[2], *Aeolothrips fasciatus* L., *Frankliniella fusca* Hinds, and *F.* sp. (*tritici* group) were collected on the injured plants, the first-named was found to be responsible for the major injury. Thus far this thrips has been reported from Ohio, New York, Pennsylvania, Virginia, New Jersey, Connecticut, Rhode Island, Massachusetts, and Canada.

The only publication dealing with the injury and habits of this insect

[1]Order Thysanoptera, Family Thripidae. The Taeniothrips were verified by American and European authorities as *T. gladioli* M. & S.

*Authors alphabetically arranged.

Dr. Harold Morrison kindly identified the species of thrips which were collected during the course of these studies.

[2]Moulton, Dudley, and Steinweden, J. F. 1931. A New Taeniothrips on gladiolus, Can. Ent. 63: 20–21.

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Plate 11. Injury by *Taeniothrips gladioli* M. & S. on gladiolus.

FIG. 1.—Rasped and silvered areas on foliage and young spike. × 2/3.

FIG. 2.—Badly injured flower spike of variety Virginia showing rasped and bleached areas on petals and the crimped edges of the petals resulting from insect feeding in the early bud stage. The flowers will probably open no farther. × 2/3.

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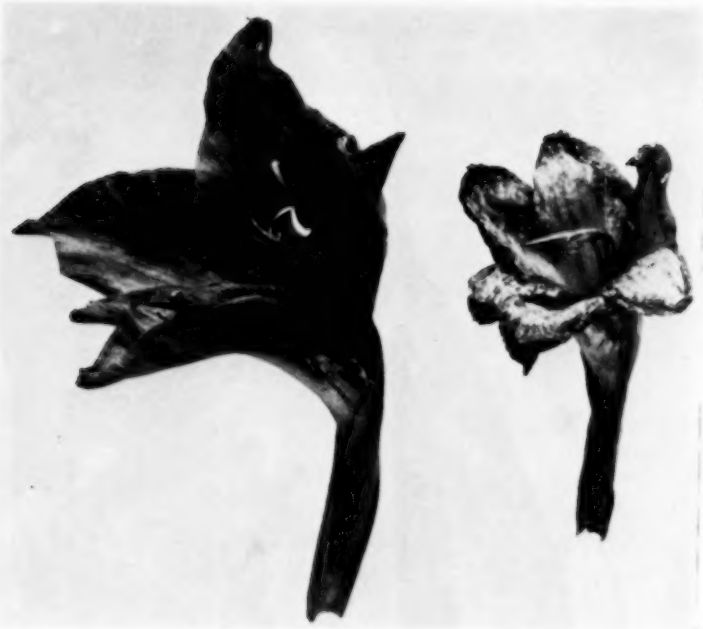

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which has come to our attention is an article[3] by Dr. B. O. Dodge of the New York Botanical Gardens. His observations as published in his paper and conducted independently are substantiated by those related in the present discussion.

INJURY. The injury caused to gladiolus by *Taeniothrips gladioli* is of two kinds, (1) the "silvering," occasioned principally by the adults and to a certain extent by the larvae, and (2) the injury on the leaf and bud sheaths and on the unopened flowers, produced mostly by the larvae and to a less extent by the adults. This classification of injury is made because the adults feed in larger numbers on the exposed plant parts while the larvae feed in secluded and protected places. Either stage of the insect, however, will cause similar injury on a given plant part. Injury on the leaves and on the young flower spikes before the flower buds separate is manifested by the rasped, sunken, and bleached or silvered areas (Plate 11, Fig. 1) similar to those produced on chrysanthemum by *Heliothrips femoralis* Reuter. This injury is more striking than is that produced by some of the other thrips on their respective hosts. The feeding of the young on the inner surface of the bud sheath probably contributes to the gradual drying, turning brown, and dying of this part of the flower spike. The normal color of the inner surface of the bud and leaf sheath is green with delicate cells full of sap. This tissue when injured by thrips is more brittle than the uninjured parts and the surface appears brown and sunken in more or less contiguous areas. As the flower spike pushes out the stem is exposed to the feeding of the thrips in the topmost leaf sheath. Such injured parts appear brown, rather warty, and brittle.

Injury to the flowers is of two types, both of which may occur on the same bloom (Plate 11, Fig. 2; Plate 12, Fig. 1), (1) the rasping and bleaching of the petals forming the corolla tubes, most noticeable on the red and purple varieties, and (2) the injury to the tips of the petals whilstill in the bud, which causes them to dry and become crimped and pree

[3]Dodge, B. O. 1931. Gladiolus badly infested with thrips. Jour. N. Y. Botanical Garden 32: 205–210.

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Plate 12. FIG. 1.—Injury by *Taeniothrips gladioli* M. & S. to a single gladiolus flower of the variety Purple Glory (right) beside an uninjured flower. Note the crimped edges and the rasped and bleached areas in the throat of the flower. × 2/3.

FIG. 2.—Injury by *Taeniothrips gladioli* M. & S. on corms of gladiolus variety Halley. Note the severe russeting on corm at bottom and less injury on corm at upper right with no injury on upper left one. Also note absence of injury in areas about buds of the two injured corms where protection was afforded by the tight fitting cap-like scales. × 1.

venting the normal opening of the flower. The adults are responsible for most of the bleaching after the flowers are fully expanded, while the larvae injure the edges of the rolled petals while still in the bud sheath. When this injury is slight it results in a puckering of the edges of the petals as the flower is able to expand more or less completely; however, when more severe, the flowers fail to open and in such instances the young continue to breed and to feed on the inner surface of the corolla tube, the pistil, and the ovary. The injury to the seed pods or ovaries has resulted in a failure of the plants to produce seeds, as was observed by several hybridizers.

The corms after being harvested and placed in storage have also been found to be attacked by the thrips. This results in a russeting of the areas fed upon owing to the formation of corky tissue (Plate 12, Fig. 2.) The ultimate effect of such injury has not yet been determined, but it may be a factor in facilitating the entrance of disease organisms especially those of the Penicillium group as well as shrivelling due to the increased loss of moisture from the corm.

Economic Importance. The loss of flowers is of chief concern to most growers. Observations showed as high as a 95 per cent loss in flowers in a field of 300,000 corms. The average number of corms planted per acre is 75,000, and this figure, therefore, may be used in estimating the value of the flower crop. If each corm produces one saleable spike the crop of cut flowers would amount to approximately $1,562 on the basis of 25 cents per dozen.

Another angle to consider in these losses is that which concerns the hybridizer, fancier, and amateur. While the commercial varieties may be purchased for as low as $10 per thousand, a single corm of a recently introduced variety may be valued at $10 or more. Flowers produced from such novelties are not only a source of pleasure but also enter into competition in flower shows where considerable public interest is created and the value thereof can not be estimated. Furthermore, the breeding of new varieties and their sale as corms is an important source of income to certain hybridizers whose principal market for these novelties is the amateur. Owing to their beauty and the ease with which they may be grown in the garden, the gladiolus have achieved a widespread popularity. Since the appearance of the thrips and the failure to combat it successfully with the generally recognized control measures, however, the interest of the amateurs in this flower has considerably lessened. Also the disfiguring of the corms occasioned by the feeding of the thrips detracts from their clean appearance and thereby reduces their sales value. These factors are being noticeably felt by the producers.

Hosts. From the information now in hand *Taeniothrips gladioli* seems to be rather restricted in its choice of host plants. It is primarily a pest of the gladiolus but was found breeding on three other species of plants—tigerflower (*Tigridia* sp.), Montbretia (*Tritonia* sp.), and the torchlily or pokerplant (*Kniphofia* spp.). All of these hosts are in the iris family, Iridiaceae (Ixia group) except Kniphofia which belongs to the family Liliaceae. In August, a few adults were collected from flowers of Buddleia hanging over a row of infested gladiolus and others were found among the glutinous hairs of Petunia where they apparently became entangled while migrating from near-by gladiolus. The apparent absence of this species of thrips on many other ornamentals, vegetables, and weeds was very striking. During late October the adults were collected on foliage and in the leaf sheaths of the Japanese and German types of iris and a few in flowers of Calendula, Dianthus, and Lathyrus (perennial sweet pea). All of these collections were made near areas from which gladiolus had been recently harvested, so it would seem that the adults had migrated to these plants and were feeding only temporarily. At this time adults were found in large numbers among the bases of leaves in crowns of the large *Kniphofia uvaria* and in the flower spikes and among leaves of the smaller Kniphofia hybrid varieties. The two types of iris and the pokerplants seem to afford the greatest possibility for furnishing overwintering conditions, because of their remaining green during the winter.

Life History and Habits. No studies were made of the life history and rate of development of this thrips but development is undoubtedly rather rapid. Adults and larvae were present at all times during the period of observation.

In the field on bright days only a small proportion of the insects seem to be exposed on the surface of the plant. And very few of these are larvae. On cloudy and slightly rainy days and in the early morning and late evening more adults and many larvae are found on the surface. The greater numbers are found in the leaf sheaths and flower parts, such as the bud sheath and corolla of the unopened flowers. The eggs are inserted in the plant tissue in these protected parts.

Larvae pupated in flowers and leaf sheaths when infested material was confined in boxes or wrapped in paper. During October pupae were found in the field in large numbers on the soil surface beneath the infested cut-off tops left after harvesting. In unharvested fields where the soil was rather dry pupae were found in crevices about the base of plants to a depth of 3 inches. In contrast with the pupae of the pear

thrips, *Taeniothrips inconsequens* (Uzel)[4], which spends the winter in a definite pupal cell, those of *T. gladioli* are unprotected by any sort of pupal cells.

Apparently a moist condition is required by the insect in the pupal stage. Many pupae were drowned by water from recent rains filling up the depressions in which they were located.

During late October no pupae were observed in the soil from which plants had been dug ten days to two weeks previously. Pupae collected on October 26 had all emerged as adults on November 3, or eight days later. Probably this stage is much shorter in the midseason when temperatures are higher.

If the insect overwinters out of doors it probably does so as an adult, either on some living plant or in some rubbish. It is believed that the delicate unprotected pupae in the soil could not survive the winter.

Breeding apparently continues in the storage cellars, since larvae, pupae, and adults were found beneath scales on corms which had been dug for two and one-half months. The presence of the insect on corms in storage would account for the wide dissemination, through the great interchange of stock by commercial growers as well as the numerous purchases of small lots by private home gardeners in all parts of the country.

The only natural enemy observed was a frequently occurring predator, *Orius insidiosus* Say (Family Anthocoridae), nymphs and adults of which were observed to feed on the larvae, pupae, and adults of this thrips.

CONTROL. As previously stated, this insect lives in secluded and protected places on the plant and relatively few are exposed on the outer surfaces at any one time, even on cloudy or dull days. For these reasons control by spraying or dusting, even under the favorable condition of overcast days, would be very difficult and require frequent and careful applications. To meet with general approval, the insecticide would have to be one which would not leave an objectionable residue or otherwise injure the blooms for sale or exhibition purposes. The application of the present known control measures for thrips in general can therefore be considered as palliative rather than remedial.

Because of the possibility that this insect may live entirely or for the most part on corms in storage, efforts to develop commercial control under such conditions will probably be more practical than will a spray program conducted during the active growing season. Even though it is later found that the thrips overwinter out of doors, the control of the

[4]Essig, E. O. 1926. Insects of Western North America, pp. 189–190. The Macmillan Company.

insects in storage to reduce the injury to corms would seem justifiable. To control this insect in storage, therefore, some method of fumigation such as the use of hydrocyanic acid gas as evolved from calcium cyanide or sodium cyanide, or possibly the use of carbon bisulfide, may be found satisfactory. These materials[5] have not been employed against thrips. Unpublished data covering tests performed in Washington, D. C., by C. A. Weigel in 1928 indicate that calcium cyanide was effective as a control against Baker's mealybug, *Pseudococcus maritimus* Ehrh., when used at the rate of one-half ounce per 100 cubic feet of space with an exposure of five hours. This treatment was not harmful to the dormant and dry corms, and normal flowers were produced from stocks so treated.

Dr. Dodge[3] quotes the suggestions of other workers as to control by dipping the corms for 15 or 20 minutes in a solution containing 1 ounce of free nicotine and 3 gallons of water or submerging them for one hour in a nicotine and soap solution.

If any of the above treatments are used, the eggs would probably be unaffected and the treatment would have to be repeated at stated intervals after the eggs had hatched.

Submerging the corms in hot water in the same way as is done for disinfecting narcissus bulbs may also prove satisfactory. Again, this method has not been tested against thrips but it has been used[6] successfully to kill the mealybug, *P. maritimus*, on gladiolus. In these tests the corms were submerged for ten minutes in hot water at a temperature of 120° F. No injury to the corms or to the subsequent flower crop was determined in recent unpublished tests. If this method is used, the eggs as well as the larvae and adults would probably be killed and only one treatment will be needed.

Treating the corms with naphthalene flakes, paradichlorobenzene, nicotine dust, or freshly ground tobacco stems may possibly prove of some value. These treatments, if effective, would be especially applicable to the needs of amateurs where small lots in bags must be treated.

The information and suggestions presented in this article are based on

[5]Since the manuscript was prepared, control experiments have been inaugurated. The results thus far obtained indicate a complete kill of larvae, pupae, and adults on unpeeled corms by fumigating with granular calcium cyanide using one-fourth ounce per 100 cubic feet of space with an exposure of 3 hours. Complete kill was obtained on certain corms where the insects were concealed under as many as six layers of scales. As these corms had been in storage for several weeks, the scales had dried sufficiently to allow the gas to penetrate to the insects beneath. The effectiveness of the gas to the eggs is now under observation.

[6]Smith, Floyd F., 1927. Pseudococcus maritimus Ehrhorn, a pest of gladiolus and calla. Jour. Econ. Ent. 20: 843–844.

the observations thus far completed and it is hoped that they will be of value to other investigators of this serious problem and hasten its solution and the development of successful control measures.

SUMMARY. *Taeniothrips gladioli* M. & S. has caused serious injury to gladiolus during the past season in several northeastern states and Canada, occasioning considerable losses. The injury consists of a "silvering" of the foliage and malformation and streaking of the flowers. The host plants are rather restricted and include Montbretia, Tigridia, and Kniphofia, belonging to the families Iridaceae and Liliaceae. Development seems to continue throughout the growing season, as all stages were present during the period of observation. Adults and larvae are found for the most part in the protected portions of the plant and relatively few are exposed on the surface at any one time. The pupal stage was found in the soil. Development was also observed to occur on the corms while they were in storage, and the probability that the thrips overwinters under these conditions offers a possibly more favorable means of combating it than the application of field control measures. Several methods of control applicable to storage conditions are discussed.

## INJURY TO HOLLYHOCK AND MARIGOLD BY THE POTATO LEAF HOPPER, *EMPOASCA FABAE* (HARRIS)[1]

By FLOYD F. SMITH, *U. S. Bureau of Entomology*

ABSTRACT

The disease-like injury as observed on hollyhocks and African marigold in several states during the past season is described for each host. The symptoms have been reproduced experimentally by the feeding of *Empoasca fabae* (Harris) on caged plants.

During the past several years the economic importance of the potato leaf hopper, *Empoasca fabae* (Harris), has become more generally known because of its proven responsibility for causing on many of our economic plants certain striking types of disease-like injury resulting from physiological disturbances. Some of these plants are potato,

[1]Order Homoptera, Family Cicadellidae.

Plate 13, 1.—Injury to hollyhock leaf taken from a plant growing in a garden. × 2/3; 2.—Experimentally produced injury on hollyhock. Three adults of *Empoasca fabae* fed for six days on the two leaves to the left and the photograph was taken nine days after removal of the insects. The uninjured check leaf compares the size of injured and uninjured leaves. × 4/5.

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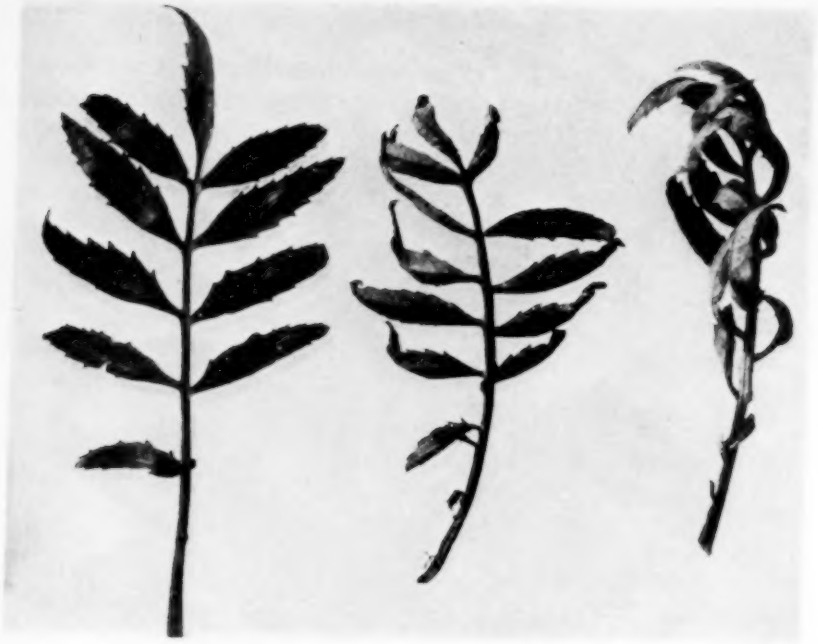

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apple, alfalfa, clover, bean and other legumes, eggplant, and dahlia. Because of the wide variety of plants fed upon by this insect, it is only natural to assume that additional cases of damage to other host species will be found. During the season of 1931 two such cases on ornamental garden plants have come to the attention of the writer. A type of leaf injury similar to hopperburn of potato was observed on hollyhock, *Althea rosea*. African marigold plants, *Tagetes erecta*, including both the tall-growing and the dwarf varieties, exhibited a curling and reddening of leaflets and the stunting and killing of young tips. Heavy infestations of Empoasca in all stages were associated with injured plants, and rearings of males from nymphs collected on both hollyhock and marigold were identified as *Empoasca fabae* according to the genital characters.[2]

A description of the symptoms developing externally on each host in the open and a discussion of their reproduction experimentally follow.

INJURY ON HOLLYHOCK. The injury was first observed on hollyhock in June, 1931, in Clarendon, Virginia, and it increased during July. The same type of injury was also observed during the season in the District of Columbia, Maryland, New York, and Ohio. The symptoms consist of the upward curling of the tips of the leaf lobes with a browning and drying of these parts. (Plate 13, Figs. 1 and 2.) A yellow band borders the browned areas and blends into the normal green tissue toward the center of the leaf. The injured areas evidently turn yellow first and then become brown as the tip dries and curls, as indicated on the lobes of other leaves. This sequence of development of symptoms was also observed on the experimental plants. The injury in various stages of development from normal leaves to that including approximately one-third of the leaf area was observed on the same plants. On the lower surface of the injured leaves the veins appeared bleached or silvered for some distance toward the base of the leaf from each "hopper-burned" lobe. Lateral veins and veinlets also showed the bleached condition. On the upper surface, these injured veins were more prominent and of a more yellowish color than normal ones. Hollyhock seems to be a very

[2]Gratitude is here expressed for aid given by D. M. DeLong, F. W. Poos, and P. W. Oman in identifying a portion of the males and in verifying the author's determinations of the remainder.

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Plate 14, 1.—Injury to marigold. Uninjured check leaf to left. Leaves to right show twisting of petioles and curling of leaflets. × 2/3; 2.—Experimentally produced injury on dwarf marigold. Three adults of *E. fabae* fed for eight days on the plant to the left and caused wilting of leaves and stunting of growth. Photographed two days after removing the insects. × 4/10.

vigorous growing plant and the plants bearing the injured leaves grew to a height of seven feet, produced good flowers and matured seed. Plants growing in the shade on the north side of buildings and showing no marginal burning of leaves flowered no better than the injured ones in the full sun. The chief detraction seems to be the unsightly appearance of the foliage owing to the browned and curled condition of the leaves.

INJURY ON MARIGOLD. The injury on marigold plants was also first observed in late June in Clarendon, Virginia, and was later observed in the District of Columbia, Maryland, Pennsylvania, New York, and Ohio. The symptoms on this plant are very striking and may be separated into two types—the distortion and discoloration of the older leaves and the killing of the young terminals. The injury to the leaves consists of the cupping upward and reddening of leaflets and the twisting of the petioles 45 to 90 degrees on their axes or the bending of them laterally. (Plate 14, Fig. 1.) The rotary twisting of the petioles seemed to follow the lateral bending in the development of the symptoms. The leaflets cupped upward on all margins, then curled up and over the midrib. If such leaves were shaded slightly they remained green or slightly yellowish green in color but the leaflets whose under surface was exposed to the full sun developed a deep purplish red on the under side. Other leaflets on the opposite side of the same compound leaf, whose lower surface was not thus directly exposed to the full sunlight, remained green. The reddening seemed to begin at the tip of the leaflet, then progressed downward with the midvein and laterals forming an apex of a triangle of the coloration. The interveinal tissue developed the anthocyanin before the veins in some cases and in others the veins were more deeply colored. The upper surface of the leaflets whose lower surface was deeply reddened did not exhibit the discoloration. The twisted leaves, both petioles and leaflets, were rather stiff, brittle, and considerably thickened when compared with the normal leaves of the same age.

The other phase of the injury is the complete wilting of the tips and the young leaflets on some branches. (Plate 14, Fig. 2.) These leaves became yellow and dry and new laterals developed below the point of injury.

The injury on the dwarf varieties of marigold was much more severe than that on the tall-growing varieties. The flowering of the dwarf varieties was delayed until September because of the repeated killing of the tips. This severe type of injury was not often observed on the tall-growing varieties during the summer, but curling and reddening of

leaflets was noted, which, however, did not prevent flowering. After about September 1 the injury decreased in evidence on marigolds and the dwarf varieties began to flower.

EXPERIMENTAL PRODUCTION OF INJURY. Since large numbers of leaf hoppers belonging to the genus Empoasca were breeding on the injured plants, these insects were at once suspected of being responsible for the production of the abnormal condition of the host. To test this possibility nymphs developing on hollyhock, marigold, and zinnia were reared to adult and all males after use in tests on caged plants were identified as *E. fabae*. Males of this species were also collected from *Rosa manetti*, alfalfa, and potato for use in tests. In twelve tests 66 males were used for production of injury on seedling hollyhocks and 46 males were used in 17 tests on marigold plants grown from seed or by clonal reproduction.

On both plants the symptoms developed more quickly with the same number of insects during the warmer temperatures and longer days of summer than during the fall months. In comparative tests marigold plants were more quickly and more severely injured than were hollyhocks by a like number of insects.

By confining adults in micro-ring cages on petioles of young leaves, rapid wilting or the more slowly developing types of injury, depending upon the number of insects used, was produced in the leaf part beyond the point of feeding.

Although *E. fabae* seemed to be entirely responsible for the production of the injury described on these two flower-garden plants in the localities studied, other species of insects may be involved in other areas. Heavy infestations of *Myzus persicae* Sulzer did not occasion the injury. Adults of *E. erigeron* De Long, produced a stippling of the foliage typical for this species.[3]

SUMMARY. During the season of 1931 a type of injury to leaves of hollyhock similar to the hopperburn injury on potato was observed in several states. Marigold in gardens showed a curling and reddening of leaflets and twisting of petioles and also the killing of young shoots. Heavy infestations of *E. fabae* occurred on the injured plants and the symptoms were reproduced experimentally by allowing adults of this species to feed on caged plants.

[3]Smith, Floyd F., and Poos, F. W. The feeding habits of some leaf hoppers of the genus Empoasca. Jour. Agr. Res. 43: 267–285. Aug., 1931.

# OBSERVATIONS ON MUSHROOM INSECTS[1]

By C. A. THOMAS, *Pennsylvania State College*

ABSTRACT

This paper is a summary of the biology and control of the flies and springtails which injure cultivated mushrooms. Mites, which also cause considerable damage to mushrooms, are not discussed here, but an extended account of these and of the above pests will be found in the new Bulletin 270 of the Pennsylvania Agricultural Experiment Station.

Mushrooms have been commercially cultivated in Pennsylvania since about 1885, but the greatest growth of the industry has occurred within the past twenty years. At present about 70 per cent of the mushrooms cultivated in the United States are grown in Chester and Delaware counties, Pennsylvania, and in adjacent territory. The remaining 30 per cent are scattered through Massachusetts, New York, New Jersey, Ohio, Illinois, Minnesota, Missouri, Washington and California.

With this concentration and recent rapid growth of the mushroom industry there has also been an increase in the number and destructiveness of the mites and insects which injure mushrooms. A number of species have been recorded as injurious in this country and Europe, but the following are those of chief economic importance in Pennsylvania:

ACARINA: The Mushroom Mite, *Tyroglyphus lintneri* Osborn; Long-legged Mite, *Linopodes antennaepes* Banks.

COLLEMBOLA: The Mushroom Springtail, *Achorutes armatum* Nic.; Silvery Springtail, *Lepidocyrtus cyaneus* Tullb.

DIPTERA: Mycetophilidae (Fungus Gnats)—*Neosciara pauciseta* Felt; *Sciara multiseta* Felt; *S. coprophila* Lintner; *S. agraria* Felt.

Phoridae (Hump-back flies)—*Aphiochaeta albidihalteris* Felt; *A. agarici* Lintner. Cecidomyiidae—undetermined species.

In addition to the above a number of minor pests also occur in mushroom houses, such as Woodlice, Slugs, Noctuid "looper" caterpillers, Nematodes, Rats and Mice, but as these are seldom of much economic importance in Pennsylvania, they are not discussed in this paper. The destructive mites are discussed at length in Bulletin 270 of the Penna. Agric. Expt. Station.

GENERAL PREVENTATIVE AND CONTROL MEASURES. Observations have shown that most of the pests which later appear in mushroom houses enter manure after it has been piled on the ground outside of

[1]Publication authorized by the Director of the Pennsylvania Agricultural Experiment Station as Technical Paper No. 543.

those houses. Although a few Phorids may occur in manure, while it is still in the cars, not many of the other insects and mites are to be found there, but come into the new manure pile from the soil beneath it and from surrounding soil, rubbish and materials removed from the mushroom houses. It is obvious, therefore, that an attempt should be made to prevent this invasion of the manure piles.

In the first place the composting ground outdoors should be scraped, thoroughly cleaned, and well drained before any manure is piled there. After the manure is piled it should be well composted and the outside manure should be turned to the inside at each turning. Most of the pests in a manure pile are within about six inches of the surface, as the interior manure is too hot for them. The manure should not be too wet, especially on being placed in the house.

In filling the house the manure should be run in rapidly, to retain its heat. When all of the beds are filled the house is tightly closed. The manure should then heat quite rapidly until within two to four days the upper beds may have reached a temperature of 135° to 145° Fahrenheit at a depth of three or four inches in the manure. Most of the insects and mites in this manure are either killed by this heat or are driven to the manure surface, where the temperature may be from five to twenty degrees lower than in the manure. However, the bottom beds, especially those built upon the ground, do not heat well. To aid in their heating these beds should be about six inches above the floor, and a couple of electric fans (horizontal) should be placed part way along the center aisle when the upper beds are near their top heat of about 135°F. This will help to raise the manure temperatures of the lower beds considerably and may thus drive the insects and mites to the surface. If a fumigant is used at the time of top heat, a high percentage of the exposed pests can be killed. Either calcium cyanide can be used at this time, about one pound per one thousand cubic feet of air space, or flowers of sulfur can be burned in the aisles, about 1½ pounds per one thousand cubic feet for five or six hours, care being observed because of the fire hazard with burning sulfur, and the penetrative power of both gases which may injure growing mushrooms in adjacent houses. Neither cyanide nor sulfur dioxide penetrate wet manure very far and thus pests may escape in low-temperatured beds.

Live steam has been run into houses in which the manure was at its top heat, and undoubtedly has killed many insects and mites; but unless it can be regulated so that the temperature does not go above 145°F, it should not be used, as it may so sterilize the manure that molds will grow to the detriment of the spawn.

After the house has gone through its heating and fumigation, fine-meshed screening of doors and ventilators may prevent the entrance of many mushroom flies, but many may also develop within the house if fumigation has not been effective.

Many growers are careless with the old mushrooms, stumps, etc., taken from the beds in infested houses and leave them piled outside the house. In these piles many flies breed and from them reenter the doors and nearby manure piles. All of this offal should be carried to some distance from the house and either burned or placed in a hole and covered with quick lime and soil or with kerosene, and burned.

At the end of the crop, an infested house should receive a heavy fumigation with sulfur, steam or some other fumigant just before tearing out the beds, if this can be accomplished without endangering adjacent bearing houses. After these beds are torn out, the compost should either be removed to some distance and spread out thin as fertilizer on the fields, or should be sold and taken away from the farm. Soil from these fields should not be used for casing soil for at least several years.

If the house has been badly infested with mites, etc., a heavy sulfur or steam fumigation, just before refilling the house, will kill a considerable percentage of any insects or mites which may have remained there.

## Mushroom Flies

Sciarid Flies. These are considered as of one species. The larvae of Sciarid flies are undoubtedly the most injurious and most widely distributed of the insect pests of cultivated mushrooms. The white oval eggs of Sciarids are laid in the manure, or on the casing soil, or mushrooms, and the larvae destroy the mycelium in the beds or make extensive galleries up into the stem and cap of the mushroom. The larva of the Sciarid fly is readily distinguished from other larvae in the mushroom house by its black chitinous head attached to a white semi-transparent body.

Pupation generally occurs in the manure or casing soil of the bed. The total life-cycle of a Sciarid occupies from 2½ to 3 weeks at mushroom house temperatures. The adult flies generally do not appear in numbers until at least a month or more after the manure is placed in the beds.

Phorid Larvae (*Aphiochaeta* species) are also white, but have only the small black chitinous jaws and no head capsule like that of the Sciarid larva. Many eggs are laid on the manure pile outside the house. Those larvae which survive the heating of the manure after it is placed in

the beds in the fall, frequently cause some injury and considerable alarm among the growers by chewing off the mycelium as fast as it grows out from the newly-planted spawn piece. As soon as they pupate, this feeding ceases and the mycelium then generally makes its normal growth through the manure. This type of injury occurs in the warmer weather of early fall and is usually not common through the winter. It has been especially noticeable during the fall of 1931, due perhaps to so much wet manure going into the houses, as Phorids seem to prefer wet manure.

Phorid larvae may again cause injury in late spring and early summer by boring the caps and stems of the mushrooms much in the same way as Sciarid larvae. Adult Aphiochaeta flies are more abundant in mushroom houses in the fall, spring and early summer. These flies give off a peculiarly penetrating acrid odor when they are active.

CECIDOMYIID LARVAE (species undetermined.) Sometimes occur in large numbers in mushroom houses where they may be found crawling singly on the beds, or in large groups on the caps, stems, at the base of the stems or between the gills. They may burrow into the tissues on the outside of the mushroom, turning these tissues brown, and some also follow through the galleries made by Sciarid and Phorid larvae. The exact economic status of these larvae has not been determined, but they generally are not common everywhere nor very destructive in this country. In color, these larvae vary from nearly white and semi-transparent to orange and opaque. They seem to feed to some extent on mites, etc., on the mushrooms. The pupae have orange-colored bodies, as do also the very small adult flies. The writer has several times noted evidence of paedogenesis among these larvae.

Other Diptera and their larvae, as Drosophilids, *Leucophenga varia* Wlk. and related species have been found in mushroom houses or in the beds, but have not been noted as of economic importance. The Drosophilids were bred from decaying mushrooms. Platypezids—(*Platypeza minorata* Banks) were reared from wild mushrooms out doors but the writer has never found them in a mushroom house.

NATURAL CONTROL: Sciarid flies in mushroom houses apparently have very few effective natural enemies. The writer has reared the hymenopterous parasite *Calliceras amplus* Ashm. from *Neosciara pauciseta* Felt, but this parasite is nowhere common enough to be a factor in control.

Hungerford[2] (1919) found a Nematode worm, *Tetradonema plicans*

[2]Journ. Parasitology, V, No. 4, p. 186, June 1919.

Cobb, parasitising larvae of *Sciara coprophila* Lintner in the mid-west but the writer has not observed this parasite in Pennsylvania.

Adults and larvae of several Staphylinid beetles have occasionally been observed feeding on Sciarid larvae and pupae, and these fly stages have also been observed to be sometimes attacked by Gamasid mites (*Parasitidae*). These mites have also been found feeding at times on larvae and pupae of the Cecidomyiid.

CONTROL: Prevention should always be the first thought against these as against all mushroom-house pests. However, since flies frequently become established in the houses despite all efforts to the contrary, other methods aimed at control necessarily had to be developed. Among such methods are light traps, windows, dusts and fumigants.

Sciarid and Phorid flies are strongly positively phototropic and are readily attracted to electric lights or to small windows set into the doors or walls at the sunny ends of the mushroom house. Several types of the light trap have been developed:

(1) *Electric light-kerosene pan traps, and light-sticky paper traps:* A flat pan, containing about one-half inch of kerosene, is suspended about one-half to one foot below an electric light placed on the ceiling above each end of the central aisle of the house. The heat from the light slowly vaporizes the kerosene, thus adding to the effectiveness of the trap. Large numbers of Sciarid and Aphiochaeta flies have been caught in these traps. In one heavily infested house, the writer collected over thirteen quarts of Sciarid flies from three traps in a period of 48 hours. Seventy per cent of these were females, mostly with eggs.

Instead of the kerosene pan, tanglefoot papers are frequently hung about a light, and are changed frequently.

Another type of trap consists of an electric light hanging within a square glass box. On the outside of the glass, tanglefoot is spread thinly, and this, with the collected flies, is scraped off and replaced when necessary.

Ordinary white and blue-white electric light bulbs of about 40 to 50 Watts are effective, while a photographic ruby bulb was not at all attractive to these flies.

(2) *Windows:* Single panes of glass, placed in the doors or the end walls of the house, let in daylight which is very attractive to mushroom flies. The glass should not be too large as it will let in too much light, and flies will alight on the ends of the beds and oviposit before going to the glass. To catch the attracted flies, tanglefoot or other sticky papers may be placed beside and directly below the glass, or tanglefoot may be painted directly on the glass and scraped off when necessary. A

small pan containing a little kerosene may be placed at the lower edge of the glass, containing a small sponge to vaporize the kerosene. Another variation is to bore a hole in the door and insert the mouth of a pint jar, containing a little kerosene, in the outside of the hole.

The traps just described cannot be expected to catch all of the flies, but they generally will take off the excess, and should be supplemented by dusting, fumigation, etc. Light traps should be started as soon as the manure loses its high temperature after filling.

Some growers remove many of the flies from their houses by opening the doors and allowing them to fly out. However, this may only serve to infest other houses and nearby manure piles, and in very cold weather, although many flies go outside and perish from the cold, many also remain dormant within the house in the beds, and thus escape. The flies are most strongly attracted to lights when most active because of being warm.

Dusts. Several commercial dusts used on other insects, are also used by mushroom growers. Pyrethrum is the active substance in most of these dusts. Dusts of pure pyrethrum have been almost entirely replaced by dusts containing certain percentages of pyrethrum plus varying proportions of some inert carrier such as gypsum, etc. "Black Arrow," "Fly-X" and several others are in common use, with varying results. Such variation in kill, however, is as often due to difference in kind and activity of flies present in the house, and to the temperature and humidity conditions, as it is to any difference in actual toxicity of different lots of the same make of dust. For instance, Phorid flies are usually much more resistant to the various dusts than are Sciarid flies, and a considerably higher percentage will recover from the same dusting. Also, houses dusted at 55°F. show considerably less kill of flies than those dusted above 60°F., as many flies will remain inactive behind the boards and in the beds at the lower temperatures and therefore are not exposed to the dusts.

Dusting should begin early and should be repeated when needed. The house should be slightly warmed for several hours before dusting. About two pounds of dust should be used each time in a 60 foot house. The job should be done thoroughly.

Pyrethrum dusts usually will not harm mushrooms, but may cause a slight yellowish stain if they fall upon the surface of wet mushrooms.

These dusts are occasionally used against Sciarid larvae which sometimes appear upon the casing soil in large numbers after the beds have been heavily watered.

Sprays. Ordinary fly sprays of the kerosene-derivative-pyrethrum ex-

tract-essential oil type will kill mushroom flies, but generally should not be used in mushroom houses as the oils contained in them are toxic to mushrooms and may cause them to turn brown, crack open, or become deformed.

FUMIGANTS. (a) *Tobacco compounds:* The writer has tried a number of the tobacco fumigants which are now on the market for greenhouse fumigation. Although a heavy fumigation with a burning tobacco fumigant containing a high percentage of nicotine will kill many flies, there is usually considerable recovery, especially of the Phorid flies. These fumigants do not penetrate into the beds to any appreciable extent, hence have no effect upon the larvae contained there and must be frequently repeated. The writer has seen no deleterious effects on the mushrooms, but would advise removing the good mushrooms before fumigation.

Several fumigations with a tobacco fumigant containing only two per cent nicotine gave poor results and a high percentage of recovery.

(b) *Cyanide compounds:* The gas from calcium cyanide is quite toxic to mushroom flies at certain concentrations, and if correctly used under certain temperature and moisture conditions, usually will not have any injurious or lasting effect upon the mushrooms or mycelium. Not more than about 1 to 1½ ounces of calcium cyanide should be used for each 1000 cubic feet of air space in the house. The aisles should be slightly dampened before spreading the cyanide on them, but the cyanide should not fall into standing water. The surface of the beds should be slightly dry, and the surface of any mushrooms upon the beds should also be quite dry, as moisture upon the mushroom surface may lead to burning of them.

The house temperature should be at least 60°F. and preferably slightly rising, and the relative humidity should be comparatively low.

Failure to obtain a kill with cyanide may be due to leakage because the house is not tight enough; to absorption by the moisture of beds; to the temperature being too low so that the flies are not active or remain behind the bed boards. The cyanide gas will not penetrate very far into the beds to affect the flies and larvae there, especially if the beds are damp.

When Phorid larvae cause injury by chewing the spawn piece and up into the mushrooms in the fall, some control has been obtained by warming the house slightly to hasten the development of the larvae into the pupal stage. This also stimulated the mycelium and made the mushrooms develop so rapidly that the larvae did not have so much opportunity to work up into the stems and caps. The higher temperatures

should not be too prolonged, however, as warm weather destroys many small mushrooms and is also favorable to the development of Mycogone and other molds and bacteria.

## Springtails

In Pennsylvania at least two species of Collembola cause some injury in mushroom culture. These are *Achorutes armatum* Nic. and *Lepidocyrtus cyaneus* Tullb., and also rarely a species of *Isotoma*. In midwestern mushroom houses several species of *Isotoma*, *Schöttella*, etc., have also been found injurious. Many growers believe that springtails cause no injury, but this is largely because of their minute size and because much of their damage is done within the beds and thus escapes notice.

Springtalis generally enter the manure piles from the soil and are carried into the house with the manure. Many are undoubtedly killed by the high temperatures attained by the manure in the upper beds soon after the house is filled, and many are driven to the manure surface, where, although sometimes subjected to temperatures as high as 121°F., some may escape unless killed by fumigants.

In the bottom beds, however, which frequently do not attain even 110°F., many springtails are not killed. After the house cools these come out and accumulate in gray piles on the ends of the aisles near the doors for from a few days to a week or more, then crawl up nearby posts and thus may spread into every bed in the house.

Springtail injury consists in destroying the mycelium in the beds as well as in the newly planted "spawn" pieces, and in chewing the surface of growing mushrooms. Fortunately springtails are not usually so abundant as to be injurious in many houses in any one season. Injury to the mycelium and spawn piece is generally worst in the bottom and other lower beds. Since *A. armatum* prefers damp conditions, its injury may be more pronounced in low damp houses and in mines and caves.

The piles of this springtail in the aisles give off a faint musty odor.

Natural Enemies. *A. armatum* and *L. cyaneus* have a few natural enemies in mushroom houses, but these seldom constitute an effective check. The writer has observed the following feeding on springtails: Gamasid mites (*Parasitus* spp.); *Bdella* sp.; the Hemipteron, *Triphleps insidiosa* Say; adults and larvae of several small Staphylinid beetles; and adults of the Anthicid beetle, *Tomoderus constrictus* Say.

Control. As with other pests, prevention should always be the first consideration. The manure should be thoroughly composted, and in turning, manure from the surface which contains the springtails should

be thrown into the center of the pile. Manure piled on concrete floors or on scraped and treated soil is apparently less likely to have springtails in it.

After the manure is placed in the beds, it should be made to heat rapidly by use of fans, etc. After the springtails are driven to the manure surface, about one pound of calcium cyanide per 1000 cubic feet of air space in the house should be spread on the aisles by careful, experienced men. The house is then closed for a few hours, or over night, locked, and danger signs posted.

Sulfur burned at the time of heating will also kill these and other insects and mites driven to the manure surface by the heat. About 1½ pounds are burned per 1000 cubic feet of air space for five or six hours; the house is then ventilated. This sulfur fumigation will somewhat acidify the moist manure surface of the beds to a slight depth, and molds such as *Tricothecium*, *Aspergillus*, etc., may grow profusely on this surface, but these dry up and rarely cause injury to the mushroom mycelium or mushrooms. However, it may not be possible to use sulfur fumigation if growing mushrooms are in attached houses, and there is, of course, some fire hazard connected with the burning sulfur.

When many springtails escape this heating and fumigation and later gather in the aisles, a high percentage of kill has been obtained by the use of a two or three per cent free nicotine-lime dust, dusted thoroughly over them. A band of this dust about the base of each post prevented *Achorutes* from ascending these beds for some days, but was not always so effective against *L. cyaneus*. The pyrethrum dusts used for the mushroom flies will kill some of these springtails but are not so effective as the nicotine dusts. Naphthalene and Paradichlorobenzene spread near the doors will also kill many springtails. PDB even seems to be somewhat attractive to *A. armatum*. In two houses, in which springtails had destroyed most of the mycelium in bottom beds not then cased, a high percentage of kill was obtained by spreading cheap muslin on these beds, broadcasting PDB on this, and covering this with newspapers for 48 hours. The gas penetrated about four inches into the manure and killed most of the springtails. There was little recovery, and the mycelium gradually resumed its growth. Paradichlorobenzene may have a temporary retarding effect upon the growth of mycelium and mushrooms, while napthalene broadcast on the bed was found to retard growth considerably.

When springtails appeared in large numbers on the casing soil and on the mushrooms, kills have been obtained by first removing the good mushrooms, then fumigating with a light dosage (1½ ounces per 1000 cubic feet) of calcium cyanide.

Although springtails are rapidly killed when confined with the gas of carbon disulphide, very poor results were obtained with 1 to 200 and 1 to 50 mixtures of a commercial carbon disulphide emulsion, which was sprayed on the beds and on the manure pile outdoors. Most of the springtails survived this treatment, chiefly because the carbon disulphide would not stay emulsified unless constantly and thoroughly shaken. A good emulsion gave somewhat better results.

*Achorutes armatum* and *Lepidocyrtus cyaneus* are strongly attracted to artificial lights, especially under warm, moist conditions. White and blue lights are decidedly attractive, while they appear to be indifferent to the rays from a photographic ruby bulb.

Lowering the temperature of a mushroom house, while it may somewhat retard springtail activity, also retards the growth of the mycelium and the mushrooms. It cannot be depended upon to kill springtails, as they survive low temperatures outdoors and even come out upon the snow.

In one house an undetermined *Isotoma* entirely destroyed the newly-planted spawn pieces in every bed. After fumigation of the house failed to reach them in the beds, these springtails were controlled in the following manner: Two strips of toilet paper were placed the length of each bed, and a teaspoonful of Paradichlorbenzene crystals was placed every 1½ feet along these papers. Within 48 hours practically all of the springtails had left the spawn pieces, had crawled upon the papers, and were dead or dying on or near the crystals. This shows the strong attraction of this species to PDB odors. The beds were respawned and have produced a good crop of mushrooms. This method failed to work, however, with a much larger species of springtail injuring mushroom stems in Ohio. Excellent control of springtails upon the growing mushrooms was obtained by burning 2½ pounds of Nicofume tobacco powder in the central aisle of 60 foot houses.

## THE COMPARATIVE VALUE OF DIFFERENT COLONIES OF BEES IN POLLINATION

By A. W. Woodrow, *New York State College of Agriculture, Ithaca, New York*

Abstract

Strong colonies of bees are superior to weak ones for pollination and established colonies are superior to package bees of the same strength. Strong colonies fly at lower temperatures than do weak ones.

Northern fruit growers are now using many colonies of bees annually as pollinating agents, but the wide variation in the types of colonies employed raises the question as to what kinds of colonies are most use-

TABLE 1. SUMMARY OF OBSERVATIONS OF FLIGHTS OF ALL COLONIES

| Type of colony | Weight of bees, pounds | Total flight count (135 observations) | Average flight per 2 minute period | Average flight per hour | Weight of bees as % of that of strongest colony | Average flights as % of that of strongest colony | Ratio of strength to that of strongest colony | Average flight multiplied by ratio of colony strength | Average flight for temps. 42–64°F., multiplied by ratio | Average flight for temps. 64–86°F., multiplied by ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| Overwintered colony..... | 3.00 | 7,702 | 57.05 | 1711.50 | 36.40 | 33.64 | 1 : 2.75 | 156.89 | 93.23 | 226.55 |
| Package bees on comb foundation..... | 3.00 | 6,017 | 44.57 | 1337.10 | 36.40 | 26.28 | 1 : 2.75 | 122.57 | 76.51 | 169.32 |
| Package bees in package..... | 3.00 | 5,457 | 40.42 | 1212.60 | 36.40 | 23.84 | 1 : 2.75 | 111.16 | 61.49 | 163.08 |
| Overwintered colony..... | 5.00 | 8,480 | 62.81 | 1884.30 | 60.60 | 37.04 | 1 : 1.65 | 103.64 | 65.08 | 146.49 |
| Package bees on comb foundation..... | 5.00 | 7,517 | 55.68 | 1670.40 | 60.60 | 32.83 | 1 : 1.65 | 91.87 | 57.04 | 129.44 |
| Package bees in package..... | 5.00 | 10,958 | 81.17 | 2435.10 | 60.60 | 47.87 | 1 : 1.65 | 133.93 | 98.62 | 171.57 |
| Overwintered colony..... | 1.63 | 3,178 | 23.54 | 706.20 | 19.70 | 13.88 | 1 : 4.94 | 116.29 | 47.52 | 189.35 |
| Overwintered colony..... | 4.38 | 15,182 | 112.46 | 3373.80 | 53.00 | 66.32 | 1 : 1.875 | 210.86 | 142.39 | 287.06 |
| Overwintered colony..... | 6.50 | 17,009 | 125.99 | 3779.70 | 78.80 | 74.88 | 1 : 1.269 | 159.88 | 100.05 | 219.71 |
| Overwintered colony..... | 8.25 | 22,893 | 169.58 | 5087.40 | 100.00 | 100.00 | 1 : 1.00 | 169.58 | 119.76 | 224.21 |

ful for this purpose. It appears obvious that strong colonies are greatly to be preferred, but the relative value of the colonies of different strengths cannot be determined on the basis of experience in the use of colonies in honey production. Farrar (31) made comparative counts of the flight of package bees and of overwintered colonies of equal strengths over two seasons. Owing to the limited number of counts made by him, a more detailed study seemed advisable in order to supply data on the effect of external conditions, particularly that of temperature, which should be of special value since temperature conditions during the period of blossoming are often not favorable to free flight of bees.

The present study was accordingly made at Ithaca in May 11 to 19, 1931, during the period when apples were in bloom. For convenience in counting and to avoid the confusion in colonies incident to moving, the bees were left in the College apiary, about a half mile from the orchards. The conditions to which the several colonies were exposed during each counting period were practically identical.

The flight rate of a colony may be determined by counting the bees either on entering or on leaving the hive. Since counts of bees leaving the hive is a better index to the immediate effect of external conditions, the latter method was used. The method of determining the exits was similar to that devised by Farrar. The bees were caught in cages for timed intervals as they left the hive and counted later. The cages consisted of a box 4⅜ inches square and 14⅜ inches long with an opening at the back to permit the bees to enter from the regular hive entrance. The upper part of the front and the outer part of the top of the trap were covered with wire cloth so that the bees on entering the trap would go to the screen and remain there. At the close of the period of observation, a metal slide at the back of the trap was closed to confine the bees, and the trap was then removed from the hive to count the bees. Enough traps were provided to permit trapping from all colonies at approximately the same time. The bees were counted by allowing them to escape from the cages through a wire cloth cone, being counted as they passed the tip of the cone.

Temperature, wind velocity and direction and the condition of the sky were recorded in the apiary while the traps were on the hives. These observations agreed closely with those made at the Weather Bureau Station located a short distance from the apiary, except for wind velocity.

Ten colonies were utilized in the experiment, which may be divided into three groups. The first group consisted of one overwintered colony

made up to three pounds of adult bees with approximately the correct amount of brood, one three-pound package of bees installed on comb-foundation and one three-pound package of bees allowed to fly from the shipping cage. The second group was comparable to the first, except that it consisted of five-pound units. The third group consisted of four unmodified overwintered colonies, chosen with regard to the number of frames of brood which they contained at the beginning of the experiment. These colonies consisted of one colony containing three frames of brood and 1.63 pounds of adult bees, one containing 7 frames of brood and 4.38 pounds of bees, one containing 10 frames of brood and 6.50 pounds of bees and one containing 16 frames of brood and 8.25 pounds of bees. A summary of the data from all observations is given in Table 1, and it is unnecessary to discuss these in detail.

The statements which follow are a brief summation of the results of the experiment. The flight from the five-pound units exceeded that of the three-pound units slightly, but falls proportionately below what might be expected from the number of bees which they contained. The weights of bees in all of the colonies in the three- and five-pound units at the close of the experiment indicate that some shifting of the colony populations must have occurred due to drifting. In the case of the five-pound established colony, a loss of 3% in the weight of bees occurred during the period, in spite of the emergence of bees from 9 frames of brood, while during the same period, the three-pound overwintered colony gained 54% in weight of bees. Consequently it is unsafe to draw definite conclusions from the data obtained as to the relative value of the three and five-pound units.

In order to compare the efficiency of the several colonies, average flights at different temperatures were calculated for each colony. To compare these average flights, each was multiplied by the factor obtained by dividing the weight of adult bees of each colony into the weight of adult bees in the strongest colony. If the flight from the several colonies were in exact numerical proportion, then the product of this multiplication should equal the flight of the strongest colony at each temperature. The variation from the theoretical number thus obtained represents the effect of the difference in efficiency of colonies. A study of these figures shows that, in general, at any given temperature, the flight of any colony is roughly proportional to the strength of the colony. The weaker colonies, however, flew less freely at lower temperatures and more freely at higher temperatures than did the stronger colonies. This is best illustrated by comparing the weakest colony with

the strongest (Table 2). In this case until a temperature of 72–74° was reached, the weaker colony lagged far behind the stronger, whereas at higher temperatures, the weaker colony sent out as many as or more bees in proportion to its strength than did the strongest colony, due to the relatively larger proportion of the colony population left in the hive.

TABLE 2. COMPARISON OF FLIGHT OF WEAKEST AND STRONGEST COLONIES

| Temperature °F. | Avg. flight of 1.63 lb. colony | Avg. flight of 1.63 lb. colony, multiplied by ratio of col. strength to that of strongest colony (4.94) | Average flight of 8.25 lb. (strongest) colony |
|---|---|---|---|
| 42–44 | 0.00 | 0.00 | 3.00 |
| 44–46 | 0.00 | 0.00 | 2.00 |
| 46–48 | 1.00 | 4.94 | 16.33 |
| 48–50 | 7.00 | 34.57 | 79.00 |
| 50–52 | 1.50 | 7.41 | 72.00 |
| 52–54 | 5.50 | 27.72 | 81.50 |
| 54–56 | 4.88 | 24.11 | 51.63 |
| 56–58 | 8.64 | 42.48 | 92.10 |
| 58–60 | 13.89 | 68.62 | 117.00 |
| 60–62 | 13.81 | 68.22 | 173.38 |
| 62–64 | 12.64 | 62.44 | 198.08 |
| 64–66 | 26.58 | 131.31 | 206.25 |
| 66–68 | 26.25 | 129.67 | 198.86 |
| 68–70 | 34.55 | 170.67 | 233.82 |
| 70–72 | 25.00 | 123.50 | 234.00 |
| 72–74 | 42.00 | 207.48 | 186.00 |
| 74–76 | 45.67 | 222.61 | 245.67 |
| 76–78 | 64.50 | 318.63 | 292.50 |
| 78–80 | 50.00 | 247.00 | 202.67 |
| 80–82 | 57.00 | 281.58 | 291.00 |
| 82–84 | 56.00 | 276.64 | 304.00 |
| 84–86 | 64.00 | 316.16 | 292.00 |

While the strongest colony sent bees to the field at temperatures as low as 42° F., no flight was observed from the weakest colony until temperatures above 47° were reached. Until temperatures of 52–54° were reached, the 4.38-pound overwintered colony failed to send out proportionately as many bees as did the strongest colony, although it exceeded this proportion for the entire period of observation.

It is evident that if the temperatures of the entire period had remained low, the differences in flights between the weaker colonies and the stronger would have been intensified. Under such circumstances thousands of colonies of the strength of the weakest colony used could not have equalled the flight of the strongest. In the fruit area of western New York, for example, continuous periods of low temperatures are prevalent at this season and high temperatures are exceedingly rare.

Even though some weaker colonies may send to the field a number of bees proportional to their strengths, it is evident that the actual weight of bees in a colony is an important consideration if the most

effective pollinating unit is to be obtained. It is unfortunately true that many colonies used for pollination are no stronger than the weakest colony studied in the present work. The mere presence of beehives in an orchard is no insurance of pollination, and if only weak overwintered colonies can be obtained locally, three- or five-pound packages of bees are more desirable, especially since they can be obtained for approximately the same price. However, strong overwintered colonies are obviously far superior to package bees.

LITERATURE CITED

1931. FARRAR, C. L. The evaluation of bees for pollination. Journ. Econ. Ent. 24, pp. 622–627.

## BROOD AREA AND COLONY SIZE AS FACTORS IN ACTIVITY OF POLLINATION UNITS[1]

By ROBERT S. FILMER, M.Sc., *Associate Entomologist, New Jersey Agricultural Experiment Station*

ABSTRACT

Studies with package bees as pollenators show that brood area is a more important factor in activity than colony size where packages are established a relatively short time before blooming period.

Fruit growers in areas where extensive orcharding is practiced are realizing more and more the need for bees to increase the quantity and quality of fruit produced. This demand in areas where extensive beekeeping is not practiced has created a demand for an economical means of supplying bees. There has been a movement on the part of some fruit growers to become beekeepers in order to satisfy this demand. The fact that most orchardists have little knowledge of beekeeping, associated with the careful manipulations necessary to successfully overwinter and to produce populous colonies at pollination time usually convince the orchardist, after a very short trial, that there is a need for providing more economical means of supplying bees. In anticipation of this need experiments using package bees as pollinators were undertaken at the New Jersey Agricultural Experiment Station in the spring of 1927.

The first step was a comparison of the strength of overwintered and package bees, and as activity of the bees on the blossoms and about hive entrances did not seem to be reliable criteria, colony strength at pol-

[1]Paper of the Journal Series, New Jersey Agricultural Experiment Station, Department of Entomology.

lination time was determined by weighing. The average of 3 years' results show that overwintered colonies of average strength under New Jersey conditions, contain approximately 3 pounds of bees. In view of these results the selection of the 3 pound combless package as a substitute for overwintered colonies is readily understood. Later experimentation by Hutson (1) and others showed convincingly that the activity of 3 pound combless packages was far below that of overwintered colonies. These facts led to further experimentation with larger packages and with the so-called, orchard packages, in which the bees were shipped on combs or sheets of foundation. Further experimentation showed that combless packages regardless of the size were not comparable to overwintered colonies and that the orchard package, while superior to the combless package, was at the best only 60% as efficient as overwintered colonies as pollinators.

In view of the fact that the ordinary combless package and the so-called orchard package did not prove successful as pollinators, further experimentation was undertaken in an effort to find a satisfactory pollinating unit. The next step was the establishing of package bees in hives containing drawn combs and full sheets of foundation. At this stage it was necessary to select a criteria for the measurement of activity. Many investigators have used the total bees returning to the hive in a certain period of time, while Hutson (3) in his experiments in New Jersey has used the number of pollen-carrying bees returning in a certain period of time. In either case there is cause for argument as it can be argued that all bees do not visit the blossoms or that the pollen carriers are not the only bees visiting the blossoms. As the number of pollen-carrying bees has been shown by Parker (2) to vary to a considerable extent, and the fact that large numbers of bees were noticed working blossoms without collecting pollen led the author during the past year, to make counts on the total bees as well as the pollen-carrying bees in an effort to determine which was the more reliable criteria for pollination activity.

1931 EXPERIMENTS. During 1931 counts have been made on various sized packages established on drawn combs and foundation in 10 frame hives. Where packages were established on foundation 4 ten pound pails of 1 to 1 sugar syrup was fed to each colony to insure establishment. All colonies placed on drawn combs were given two full frames of honey. In all colonies under observation the queen had been released and had started egg laying 5 days after introduction. Due to peculiarities of the season, the packages had been established three weeks before

any counts were made. The counts were made by two observers, one counting the total number of bees, while the other counted the number of pollen-carrying bees for the same period. The observers changed frequently in order to equalize any individual error in counting. Frequent checks between the two observers showed no difference in observation, while the number of bees entering the colony was less than one per second, but where the number was as high as 80 or 90 per minute the readings of the two observers would often vary by 4 or 5 per cent. All results are shown as the number of bees entering the hive in one minute and are the averages of 10 or more observations made on clear days with the temperature between 65 and 75° F.

TABLE 1. TOTAL NUMBER OF BEES ENTERING HIVE PER MINUTE IN OVERWINTERED COLONIES

| Colony No. | Total Bees | Total Pollen Carriers | Per cent Pollen Carriers |
|---|---|---|---|
| 1 | 30 | 20 | 66 |
| 2 | 49 | 35 | 74 |
| 3 | 58 | 54 | 95 |
| 4 | 60 | 17 | 28 |
| 5 | 64 | 37 | 60 |
| 6 | 82 | 75 | 90 |
| Average..... | 58.5 | 39.6 | |

Table 1 shows the results of counts on a number of overwintered colonies which in light of Hutson's (4) past experiments are accepted as having an average of 3 pounds of bees.

TABLE 2. NUMBER OF BEES ENTERING HIVE PER MINUTE IN THREE POUND PACKAGES ESTABLISHED ON DRAWN COMBS

| Colony No. | Total Bees | Total Pollen Carriers | Per cent Pollen Carriers |
|---|---|---|---|
| 1 | 37 | 23 | 62 |
| 2 | 40 | 13 | 33 |
| 3 | 51 | 30 | 60 |
| 4 | 62 | 33 | 50 |
| Average..... | 47.5 | 24.7 | |

Table 2 shows results of counts on 3 pound packages established on drawn combs.

TABLE 3. NUMBER OF BEES ENTERING HIVE IN ONE MINUTE ON THREE POUND PACKAGES ESTABLISHED ON FOUNDATION

| Colony No. | Total Bees | Total Pollen Carriers | Per cent Pollen Carriers |
|---|---|---|---|
| 1 | 43 | 11 | 25 |
| 2 | 57 | 16 | 29 |
| 3 | 60 | 21 | 35 |
| 4 | 72 | 15 | 20 |
| Average..... | 58 | 15.7 | |

Table 3 shows results of counts made on 3 pound packages established on foundation.

Discussion. Examination of Tables 1, 2 and 3 shows very little correlation between total number of bees and pollen-carrying bees. Where total bees is taken as a criterion the 3 pound packages established

Table 4. Showing the Activity Expressed in Total Bees Entering Hive per Minute with the Amount of Brood Present in Overwintered Colonies and Established Package Bees of the Same Strength (3 Pounds)

| Colony Number | Total Bees | Frames of Brood |
|---|---|---|
| Overwintered Colonies | | |
| 1 | 30 | 4 |
| 2 | 49 | 4 |
| 3 | 58 | 6 |
| 4 | 60 | 4 |
| 5 | 64 | 5 |
| 6 | 82 | 7 |
| Average | 58.5 | 5 |
| Packages established on Drawn Combs | | |
| 1 | 37 | 2 |
| 2 | 40 | 3 |
| 3 | 51 | 4 |
| 4 | 62 | 5 |
| Average | 47.5 | 3.5 |
| Packages established on Foundation | | |
| 1 | 43 | 2 |
| 2 | 57 | 3 |
| 3 | 60 | 3 |
| 4 | 72 | 4 |
| Average | 58 | 5 |

on foundation on the average show as great an activity as overwintered colonies while the same size package established on drawn combs on the average show only about 80% efficiency. On the other hand if the number of pollen-carrying bees is selected as a criterion, the 3 pound packages established on drawn combs show about 65% efficiency as compared to overwintered colonies of the same strength, while 3 pound packages established on foundation show only 40% efficiency. It is also very noticeable that there is a rather wide variation in activity of different colonies regardless of which criteria is used for comparison. Such a variation in colonies of the same strength seemed to show that some factor other than colony strength played an important part in the activity of colonies. As it was expected that unsealed brood present might be a factor examination of the brood chambers was made and the number of frames of unsealed brood noted. Tables 4 and 5

show the amount of brood present in regards to activity expressed in total bees and pollen-carrying bees.

TABLE 5. SHOWING ACTIVITY EXPRESSED AS POLLEN CARRYING BEES ENTERING HIVE PER MINUTE WITH THE AMOUNT OF BROOD PRESENT IN OVERWINTERED COLONIES AND ESTABLISHED PACKAGE BEES OF THE SAME STRENGTH (3 POUNDS)

| Colony Number | Pollen Carriers | Frames of Brood |
|---|---|---|
| Overwintered Colonies | | |
| 4 | 17 | 4 |
| 1 | 20 | 4 |
| 2 | 35 | 4 |
| 5 | 37 | 5 |
| 3 | 54 | 6 |
| 6 | 75 | 7 |
| Average | 39.6 | |
| Packages established on Drawn Combs | | |
| 2 | 13 | 3 |
| 1 | 23 | 2 |
| 3 | 30 | 4 |
| 4 | 33 | 5 |
| Average | 24.7 | |
| Packages established on Foundation | | |
| 1 | 11 | 2 |
| 4 | 15 | 4 |
| 2 | 16 | 3 |
| 3 | 21 | 3 |
| Average | 15.7 | |

Examination of Tables 4 and 5 show conclusively that regardless of which criterion is used, brood area is an important factor to be kept in mind, and is of great importance where package bees are to be used as pollinating units. In Table 4 it is also noticeable that packages established on foundation exhibit a greater activity in comparison to the brood area than the same sized colonies established on drawn combs. This increase in activity is thought to be due to the need for nectar for comb building while colonies established on foundation exhibit considerable more activity, such a pollinating unit would hardly be economical because of the necessity of feeding sugar syrup from the time of establishment until the period of fruit bloom. The fact that colonies must be established for a considerable period to allow sufficient time for the establishment of the brood area involves considerable labor. Where packages are established shortly before blooming period it is only to be expected that the efficiency of the package will be greatly curtailed. The fact that the weather conditions prior to blooming time do not encourage

the successful establishment of package bees and the uncertainty of predicting the start of the blooming period further complicates the practice of establishing packages far enough in advance to obtain maximum efficiency.

As it was thought that various sized packages established far enough in advance of blooming period to have one or more frames of brood might show a difference in activity, 2, 3 and 6 pound packages were hived on drawn combs and foundation about 2 weeks previous to blooming time. The results are shown in Tables 6 and 7.

TABLE 6. SHOWING ACTIVITY IN NUMBER OF BEES ENTERING HIVE PER MINUTE IN VARIOUS SIZE PACKAGES

| Number of Colonies | Colony Size in Pounds of Bees | Established on | Total Bees | Average Frames of Brood |
|---|---|---|---|---|
| 4 | 2 | Foundation | 62 | 1.5 |
| 3 | 2 | Drawn combs | 59 | 2 |
| 4 | 3 | Foundation | 58 | 3 |
| 4 | 3 | Drawn combs | 47 | 4 |
| 4 | 6 | Foundation | 69 | 2 |
| 4 | 6 | Drawn combs | 49 | 3 |
| 5 | 3 | Wrapped packages | 25 | 0 |
| 6 | 3 | Overwintered | 58 | 5 |

Examination of Table 6 again shows that in every case greater activity is exhibited in packages established on foundation. Examination of the data shows little or no advantage in the 6 pound package as compared to 2 or 3 pound packages. These results would tend to indicate that the 2 or 3 pound package is comparable to the 6 pound package where bees are to be established in hives. It is also noticeable that wrapped 3 pound packages on the average exhibited only 50% activity as compared to 3 pound packages established on drawn combs, or approximately 43% efficiency compared to the average overwintered colony of the same strength.

Examination of Table 7 where number of pollen-carrying bees is used as a criterion shows the same general relationship in activity of 2 and 3 pound established packages to 6 pound packages. However, measured by this criterion the efficiency of the established packages is approximately 30% that of the overwintered colonies while wrapped packages exhibit about 3.5% efficiency.

It might be well to mention at this time that a comparison of the so-called orchard package with various sized established packages was contemplated in this experiment. The bees for this experiment were ordered many weeks before blooming time with the delivery date depending on the blooming period. Peculiarities of the season were such

that delivery was called for about April 21. All combless packages were received but a telegram from the shipper advised that due to the rush of the season and the difficulty in putting up orchard packages the order could not be filled. From this experience it would seem that at the present time the so-called orchard package is not a dependable means of obtaining bees for pollination.

TABLE 7. SHOWING ACTIVITY IN NUMBER OF BEES ENTERING HIVE PER MINUTE IN VARIOUS SIZE PACKAGES

| Number of Colonies | Colony Size in Pounds of Bees | Established on | Average Total Pollen Carriers | Average Frames of Brood |
|---|---|---|---|---|
| 4 | 2 | Foundation | 17 | 1.5 |
| 3 | 2 | Drawn combs | 21 | 2 |
| 4 | 3 | Foundation | 18 | 3 |
| 4 | 3 | Drawn combs | 19 | 4 |
| 4 | 6 | Foundation | 18 | 2 |
| 4 | 6 | Drawn combs | 19 | 3 |
| 5 | 3 | Wrapped packages | 2 | 0 |
| 6 | 3 | Overwintered | 58.5 | 5 |

SUMMARY. From the facts as presented it is impossible to draw much in the way of conclusions until some agreement is reached on the selection of a criterion for activity. Hutson states as follows (3): "The criterion of activity selected for measurement was the number of pollen-carrying bees returning to the hive in five minutes. This criterion has certain disadvantages, for example, it does not take into account the bees visiting flowers for nectar, but since we cannot establish whether a bee is a nectar or a water carrier except by dissection and it is known that only a limited amount of nectar is available in the orchard, the objection is without great weight. That there was little nectar in the orchard was demonstrated by making up a colony to a population of 18 pounds, or 90,000 bees, and weighing it before and after blooming season. The hive weighed only five pounds more after the blooming season than before, and there were but 10.5 pounds of bees left out of the 18 pounds at the beginning." From this statement one would judge the reason for selecting this criterion was chiefly because of the difficulty in differentiating water carriers from nectar carriers. Granting that a certain number of non-pollen-carrying bees are water carriers, the tendency of this criterion is to underestimate the pollinating activity of a colony just as the total number of bees tends to slightly overestimate the activity. The fact that large numbers of bees can be observed on the blossoms that are not gathering pollen seems to be a fact that should not be overlooked as they are at least possible pollenators. Furthermore,

the great variation in the percentage of pollen-carrying bees in various colonies would seem a serious objection to this criterion. For these reasons the author believes that the total number of bees is the more suitable criterion for pollination studies and in summarizing has used this criterion.

CONCLUSIONS. The results of the past year's experiments seem to justify the following conclusions.

1. Due to the variation in the percentage of bees gathering pollen in various colonies of the same strength, the number of pollen-carrying bees returning to a colony in a unit of time is not a reliable criterion of activity and therefore the total number of bees returning in a unit of time is a more reliable criterion of activity.

2. That the activity in colonies of the same strength is greatly influenced by the size of the brood area.

3. That packages established on foundation exhibit greater activity than packages of a similar size established on drawn combs.

4. Where colonies are established on combs or foundations colony size had little influence in activity and as pollinating units 2 and 3 pound units were as efficient as the 6 pound unit.

5. Wrapped packages exhibit about 50% of the activity of similar sized packages established on drawn combs.

REFERANCES

1. HUTSON, RAY. 1929. Report, Dept. of Entomology, N. J. Agric. Expt. Sta., pp. 201.
2. PARKER, R. L. 1926. The Collection and Utilization of Pollen by the Honey Bee, N. Y. Agr. Expt. Sta. Cornell Memoir 98.
3. HUTSON, RAY. 1930. Report, Dept. of Entomology, N. J. Agr. Expt. Sta., pp. 177.
4. HUTSON, RAY. 1928. Package Versus Overwintered Bees for Orchard Use as Pollenators, American Bee Journal, March.

## ATTRACTION OF CERTAIN INSECTS TO SPRAY BAITS[1]

By ROBERT C. BURDETTE, *Associate Entomologist, New Jersey Agricultural Experiment Station*

ABSTRACT

The pepper maggot fly and the corn ear worm moth can be attracted by use of invert sugar as a spray bait. Arsenicals added to this spray reduces the number of pepper flies. Insecticides added to the spray for corn ear worm moth did not give any kill.

[1]Paper of the Journal Series, New Jersey Agricultural Experiment Station, Department of Entomology.

In working with the pepper maggot fly (*Spilographa electa* Say) various materials have been used for attempting to attract the flies in the field. Peterson (1) used brown sugar, honey, corn syrup and cane sugar without success. During the summers of 1927 and 1928, molasses and cane sugar were again tried in bait pans and by spraying the material on the pepper plants, but with no success. This past summer further tests were made using cane sugar and an invert sugar syrup.

Cane sugar as before showed no attractiveness for the pepper fly. The invert sugar syrup or syrline was effective in attracting the fly. Syrline is a product having from 75 to 81 per cent total sugar and is non-crystallizing. The non-crystallization of this syrup is due to the large proportion of invert sugar present.

TABLE 1. FLIES PRESENT ON SPRAYED AND UNSPRAYED ROWS OF PEPPERS

| Date | Time of Count | Number of Flies | |
|---|---|---|---|
| | | Syrline Rows | Check Rows |
| | First Field | | |
| 7/28 | 7:30 P.M. | 27 | 18 |
| 7/29 | 8:15 A.M. | 14 | 0 |
| 7/29 | 7:00 P.M. | 36 | 16 |
| 7/30 | 7:45 P.M. | 114 | 29 |
| 7/31 | 8:00 A.M. | 100 | 7 |
| 7/31 | 7:25 P.M. | 62 | 15 |
| 8/3 | 7:30 P.M. | 7 | 2 |
| 8/5 | 7:30 P.M. | 6 | 0 |
| 8/10 | 7:30 P.M. | 6 | 0 |
| Total | | 372 | 87 |
| | Second Field | | |
| 8/4 | 7:30 P.M. | 118 | 0 |
| 8/6 | 7:30 P.M. | 132 | 5 |
| 8/7 | 8:00 P.M. | 83 | 8 |
| 8/10 | 7:15 P.M. | 13 | 0 |
| 8/12 | 7:30 P.M. | 2 | 0 |
| Total | | 348 | 13 |

Table 1 shows the number of flies that were attracted to rows of peppers that were sprayed with syrline. The material was used at the rate of 6 pounds to 50 gallons of water and applied so that small droplets covered the leaves of the plants. From this table it may be seen that a rather large number of flies were attracted to the sprayed rows in comparison with non-sprayed rows. In order to check whether this attraction was due to the seeking of water by the flies, tests were made in comparison with rows where water alone was used. No difference was noted in the number of flies on the rows of peppers sprayed with water and those rows which remained untreated.

The attraction and feeding of the flies upon the sugar syrup offered

another method of controlling the pepper fly as well as the use of talc as a physical barrier. In the first field lead arsenate was added to the syrline spray at the rate 1½ pounds to 50 gallons on July 30th. A dye was used with the spray in order to check the flies that were feeding upon the poisoned bait. One hundred fourteen flies were counted feeding upon the spray and 29 upon the check row. On the morning of July 31 a count was made of the flies returning to the same row when syrline alone was used, this time only 100 flies were counted and 7 upon the check. Most of these flies still retained the dye in their abdomen. In the evening of July 31st, syrline and lead arsenate was used. Again 62 flies were counted on the sprayed rows and 15 on the check rows. No more sprays were applied until August 3rd when only 7 flies were found. None of these had any dye in their abdomen. Counts on August 5th and 10th showed only 6 flies on each day on rows sprayed with syrline.

Three rows in a second field of 6 acres were sprayed with syrline on August 4th. A count showed 118 flies present on sprayed rows and none on rows unsprayed. Syrline was used again on August 6th, when 132 flies were counted on the sprayed rows and only 5 on the check rows. On August 7th, syrline spray was again applied but this time zinc arsenite at the rate of 1 pound to 50 gallons was used. A count of the flies showed 83 flies on sprayed rows and 8 flies on check rows.

Syrline spray was used again on August 10th to check the field for flies, at which time only 13 flies were counted. A similar check on August 12th showed only 2 flies present in this field.

In two different fields, the use of an arsenical with the syrline as an attractant was accompanied by a reduction in the number of flies.

While using the syrline on the peppers, a number of corn ear worm moths (*Chloridea obsoleta* Fab.) was noticed feeding on the droplets of liquid.

Solutions of the invert sugar were then tried on rows of sweet corn to see if this moth could be attracted in any numbers. The syrup was applied at dusk by means of a hand sprayer using 6 pounds to 50 gallons of water. Within one-half hour after spraying the moths could be seen coming to the sprayed rows and feeding upon the syrup. In the first test, 80 moths were counted feeding on the material while no moths could be found on adjacent rows. The moths would continue feeding when a strong light was thrown on them and they could be readily picked off with the fingers.

The velocity and direction of the wind contributed greatly toward

the number of moths that could be attracted by the syrline spray. When the air was still, moths could be found on adjacent rows. Tests show that a wind of 2 or more miles per hour was necessary before moths would respond to the syrup spray. Water was used as a check in several instances, but no more moths were found on the sprayed rows than on untreated rows. Bait pans containing syrline solution were placed through several fields with negative results.

Various materials were incorporated in the syrline spray to check whether their addition would inhibit the attractiveness of the spray. Lead arsenate, zinc arsenite, sodium arsenite, arsenious acid, nicotine sulphate, rotenone, alcoholic extract of pyrethrum, and potassium cyanide were used. Of these lead arsenate and zinc arsenite seemed to interfere very little with the attraction of the syrline. Rotenone, sodium arsenite and arsenious acid made the syrup spray slightly less attractive while none or very little attraction was shown by the syrup spray when nicotine sulphate, alcoholic extract of pyrethrum and potassium cyandide was used.

Moths after feeding on lead arsenate, zinc arsenite, sodium arsenite, arsenious acid and rotenone were placed in cages to determine if these materials would prove effective in killing the moths. No moths were dead at the end of 48 hours. It is possible that the moths had not taken a quantity sufficient for killing or in the case of the arsenicals, soluble arsenic was inhibited from forming by the syrline solution. Dye when used in the solution before spraying was found in the intestine of the moths showing that the material had been taken up by the moths.

In order to make use of this attractant as a control for the corn ear worm moth, a material must be used that will have a very rapid effect on the moths, since a slow killing poison will leave time for the moths to lay eggs in the field before the poison takes effect. If a suitable killing agent can be found, the attraction of the moths to a few rows of corn in the field will possibly offer a control measure for the growers of sweet corn.

The reason for the attractiveness of the pepper maggot fly and the corn ear worm moth is not clear but may be due possibly to the fact that this invert sugar is nearer to the kind of sugar in their natural food material than sucrose. The attraction is apparently brought about by the fact that the sugar molecules are distributed in the air by the sprayer and carried by the wind to the insects.

## Bibliography

1. Peterson, A. Report of Department of Entomology, N. J. Agricultural Experiment Station for 1923–24. pp. 295–298.

# PINE OILS AS AGENTS FOR PROTECTING RUSTIC FURNITURE AND LOG CABINS FROM VARIOUS WOOD BORERS[1]

By F. M. THOMPSON, JR., M.Sc., *Research Assistant, Rutgers University*

ABSTRACT

Certain combinations of pine oils, when sprayed on the bark of rustic furniture and log cabins, are very efficient in killing the larvae of *Hylotrupes ligneus* Fab., *Oeme rigida* Say., *Callidium antennatum* Newm., or longhorned wood borers working in the wood, and will prevent further infestation of the wood for a period of at least one summer season following treatment, with no appreciable effect on the color of the bark.

Recent studies (3) with Pine Oils as means of destroying overwintering codling moth larvae have suggested possibilities of controlling other insects with these oils. The Pine Oils used in this work are of the "steam and solvent" class, extraction and occurrence of which were adequately described by Shippen and Griffin (2) in 1923.

In our work (3) with Pine Oils, we find that certain of these oils are very toxic to codling moth larvae and, at the same time, extremely toxic to living plant tissue on account of their high penetrating power. The oils tested were divided into four groups dependent chiefly on their volatility and viscosity. Group I consisted of the very light fractions; Group II of heavier fractions; Group III of the polymerized Pine Oils and Group IV of the Resins, Resinates and Abietates. The oils included in Group I show very high penetrating power and generally a low toxicity to the codling moth larvae. The oils of Group II show a high toxicity and, at the same time, high penetrating power. The oils of Group III show both decreased penetrating power and toxicity, and Group IV shows practically no penetration or toxicity at ordinary room temperatures (80° F.) except the abietates which showed high toxicity when in contact with the larvae.

In order to determine just what insects were causing the damage, a number of infested white cedar slabs were collected, caged and the emerging beetles identified. The insects causing the greatest damage were members of the order Coleoptera, family Cerambycidae, or longhorned beetles, the species found were *Hylotrupes ligneus* Fab., *Oeme rigida* Say., *Callidium antennatum* Newm.

The life histories of these three insects are similar, one complete cycle being passed each year. In describing the life-history Felt (1)

[1]Paper of the Journal Series, New Jersey Agricultural Experiment Station, Department of Entomology.

states that the beetles usually appear in the Spring, lay their eggs on the bark of the wood, the larvae hatch, bore into the wood and spend the summer months boring between the bark and sapwood. In the fall they bore obliquely into the wood where they generally, but not always, pupate. As a matter of fact, larvae, pupae, and adults have been found in the same stick of wood during the Fall of 1931. The emergence of the adults occurs the following Spring. Although we have made no systematic life history studies, observations made around heavily-infested areas lead us to believe that there is only one brood of these insects a year in New Jersey.

Another insect which was found in considerable numbers was a small bark beetle (*Phloeosinus dentatus*). The insect does not cause as severe injury as do the members of the long-horned class, but nevertheless the bark may be considerably marred by them in causing numerous shot holes about the size of a pin head in the outer layer of the bark.

Experimental work relative to controlling the above insects was laid out for the purpose of answering three questions: (1) Can borers working in the wood and bark be destroyed; (2) can infestation be prevented; and (3) can the successful treatments be applied without materially affecting the natural color of the bark?

Selection of Oils to be Tested. In our groups of oils tested on codling moth larvae and apple wood; there was one that stood out from the standpoint of toxicity and penetration, Pine Oil No. 6; one from the standpoint of penetration, Pine Oil No. 5; and one from the standpoint of toxicity, Pine Oil No. 15. In treating wood to be used for furniture and cabins care must be taken not to use any material that will discolor the wood so as to affect the natural color. All of the three oils mentioned above with the exception of Pine Oil No. 15 have no effect on the wood.

Pine Oil No. 5 is a light fraction having a viscosity of 29 sec. Saybolt 100° F., and a 10 gr. sample volatilizes completely over a period of 48 hours at 80° F.

Pine Oil No. 6, a heavier fraction, has a viscosity of 41 sec. Saybolt 100° F., and a 10 gr. sample is 60% volatile in 48 hours at 80° F.

Pine Oil No. 15 is a very heavy, non-volatile compound.

These oils were the ones selected for testing on the borers.

Experimental. Table 1 shows the results of treatments of the inside walls of a log cabin, which was heavily infested with Cerambycid borers. Two hundred c.c. of each material was applied to approximately

15 square feet of wall surface in each case. The material was sprayed on with a deVilbis paint sprayer with a coarse spray nozzle. At the time we sprayed there was a considerable amount of frass being pushed out by the borers. Our results are based on the amount of frass exuding from the walls after treatment.

TABLE 1. EFFECT OF STEAM-DISTILLED PINE OIL COMBINATIONS ON CERAMBYCID BORERS IN WHITE CEDAR LOGS IN A CABIN

| Material Used | Date Treated | Date Observed | Results |
|---|---|---|---|
| Medium Fraction | 4/23/31 | 5/6/31 | No frass |
| Light Fraction | 4/23/31 | 5/6/31 | Frass |
| Heavy Fraction | Viscosity too high to apply with sprayer | | |
| 75% Medium Fraction<br>25% Heavy Fraction | 4/23/31 | 5/6/31 | Frass |
| 75% Light Fraction<br>25% Heavy Fraction | 4/23/31 | 5/6/31 | Small amount frass |
| 50% Medium Fraction<br>50% Heavy Fraction | 4/23/31 | 5/6/21 | Frass |
| 50% Light Fraction<br>50% Heavy Fraction | 4/23/31 | 5/6/31 | Small amount frass |
| 25% Light Fraction<br>25% Medium Fraction<br>50% Heavy Fraction | 4/23/31 | 5/6/31 | Small amount frass |
| 25% Light Fraction<br>50% Medium Fraction<br>25% Heavy Fraction | 4/23/31 | 5/6/31 | No frass |
| 50% Light Fraction<br>25% Medium Fraction<br>25% Heavy Fraction | 4/23/31 | 5/6/31 | No frass |
| 25% Light Fraction<br>75% Heavy Fraction | 4/23/31 | 5/6/31 | Frass |
| 25% Medium Fraction<br>75% Heavy Fraction | 4/23/31 | 5/6/31 | Frass |

From the results obtained in this Table it is shown that only two of these mixtures seem to show any promise in destroying the insect in the wood. Our next step was to determine to what extent infestation could be prevented by treating freshly cut wood which was not infested.

Slabs (18" x 4") of newly cut white cedar wood were obtained and treated with each of the materials mentioned in the previous table. Three slabs were treated in each case with 100 c.c. of material and each group of three was separated by a group of three untreated slabs to serve as a check. The slabs were then nailed on to the side of a building adjacent to a stack of logs heavily infested with borers and allowed to remain. Observations were made from time to time to determine whether or not there was any infestation in any of the treated slabs

or untreated checks. The data obtained from this experiment is set forth in Table 2.

TABLE 2. INFESTATION OF PINE OIL TREATED AND UNTREATED WHITE CEDAR SLABS

| Material Used | Date Treated | Date Observed | Results |
|---|---|---|---|
| Light Fraction | 4/30/31 | 10/19/31 | All slabs infested |
| Medium Fraction | 4/30/31 | 10/19/31 | 2 clean; 1 infested |
| Heavy Fraction | 4/30/31 | 10/19/31 | All slabs clean |
| 75% Medium Fraction, 25% Heavy Fraction | 4/30/31 | 10/19/31 | All slabs clean |
| 75% Light Fraction, 25% Heavy Fraction | 4/30/31 | 10/19/31 | All slabs clean |
| 50% Medium Fraction, 50% Heavy Fraction | 4/30/31 | 10/19/31 | All slabs clean |
| 50% Light Fraction, 50% Heavy Fraction | 4/30/31 | 10/19/31 | All slabs clean |
| 25% Light Fraction, 25% Medium Fraction, 50% Heavy Fraction | 4/30/31 | 10/19/31 | All slabs clean |
| 25% Light Fraction, 50% Medium Fraction, 25% Heavy Fraction | 4/30/31 | 10/19/31 | All slabs clean |
| 50% Light Fraction, 25% Medium Fraction, 25% Heavy Fraction | 4/30/31 | 10/19/31 | All slabs clean |
| 25% Light Fraction, 75% Heavy Fraction | 4/30/31 | 10/19/31 | All slabs clean |
| 25% Medium Fraction, 75% Heavy Fraction | 4/30/31 | 10/19/31 | All slabs clean |
| Untreated checks | 4/30/31 | 10/19/31 | 19 slabs infested<br>5 slabs clean |

From the results set forth in this Table the data seems to indicate that the presence of the heavy fraction is the underlying factor in protecting the wood. However, in using this material we are confronted with another problem, that is the effect of this material on the color of the bark. All of the mixtures in the above table darken the bark to some degree but the ones that show promise in prevention of injury and destruction of the borer in the wood are composed of all three fractions as follows.

| | |
|---|---|
| 25% Light Fraction | 25% Heavy Fraction |
| 25% Heavy Fraction | 25% Medium Fraction |
| 50% Medium Fraction | 50% Light Fraction |

Neither of the formulae affect the color of the wood to an appreciable degree.

From data shown in the two tables, all three fractions should be used for the following reasons; the light fraction is used to increase penetration by decreasing viscosity, the medium fraction to act as the toxic agent to insure destruction of any insects in the wood and the heavy fraction to prevent re-infestation.

SUMMARY. The data set forth in this paper suggests the following conclusions. (1) Certain mixtures of pine oil fractions may be used to destroy wood borers working in the wood of white cedar. (2) These same mixtures when used to treat the bark of white cedar in the spring will prevent infestation or re-infestation for at least one summer season. (3) These mixtures have no appreciable effect on the color of the wood.

REFERENCES

1. FELT, E. P. 1906. N. Y. State Museum, Memoir 8, Vol. 2, p. 660.
2. SHIPPEN, L. P., and GRIFFIN, E. C. 1923. U. S. D. A. Bull. 989.
3. THOMPSON, F. M., Jr. 1931. Unpublished data.

## RELATION OF SHELTER TO ABUNDANCE OF PEAR MIDGE

By F. Z. HARTZELL, *New York Agricultural Experiment Station, Geneva, N. Y.*

ABSTRACT

Infestation by the pear midge (*Contarinia pyrivora*) was found to vary inversely with the distance from the source of shelter. Data and analyses of orchard environment are given upon which the fact is believed to be established.

The pear midge (*Contarinia pyrivora*) is an important pest in certain pear districts of New York. Insecticidal control of the insect not only adds to the cost of producing a crop, but also is uncertain. This uncertainty is largely due to the fact that the period for effective treatment is short, which makes difficult the proper timing of the applications so as to kill the insects before they deposit eggs. For these reasons it is believed that any method whereby the population density can be greatly reduced at low cost will be welcomed by pear growers.

HISTORY. The writer's first insecticidal experiments for the control of pear midge were conducted at Hudson, N. Y., in 1930. Two seriously infested commercial orchards were used for the tests. The sprays were applied on most plats first when the blossom buds were in the cluster-bud stage and again two days later. In order to measure the effect of the treatment counts of midge-infested and perfect pears were made about three weeks after blossoming. All the fruit on the lower limbs

to a height of about eight feet was examined and counted, and usually such data were secured from all the bearing trees in the experimental areas. During the progress of the counting it soon became evident that, regardless of treatment, certain portions of each experimental area contained much heavier infestations than was to be found on the remaining trees. These differences were not correlated with variation in type or texture of soil. The only hypothesis that seemed to agree with the data was the following:

The areas showing the highest percentage of infested fruit were those most protected from the wind. In order to further test this hypothesis ecotopographic maps of the orchards were drawn and the percentage of infestation was placed in the area occupied by each tree. Again the relation between midge population density and degree of shelter from the wind seemed to be plainly indicated. Further study was greatly assisted by graphs which emphasized the fact that where spraying operations did not interfere with the relative number of midges on the various trees, the infestation decreased in a regular manner as the distance from the source of shelter increased, and that this relationship represented a parabolic rather than a linear function of the distance, as is described below.

STUDIES IN INDIVIDUAL ORCHARDS. *Orchard No. 1.* This planting consisted of about 1000 Clapp Favorite pear trees, the oldest of which had been set about 12 years. However, there had been numerous replacements for trees that had died, therefore the number of bearing trees perhaps did not exceed 850. The main experimental block was in the southeastern portion of the orchard and included an area occupied by 360 trees of which 300 were of bearing age. The entire planting joined other orchards on two sides. The southerly side was bordered by a very young orchard and land devoted to annual crops except from tree 14 to tree 28 where a patch of woodland paralleled the pear trees at a distance of about 20 feet. Since the pear trees were from 15 to 18 feet in height and the forest trees reached a height of between 30 and 40 feet above them, protection from the wind was marked. Moreover, a considerable number of cedar trees were mixed with the hardwoods, which caused the canopy to be very dense, thus still further intensifying the shelter. The heaviest midge infestation in this planting occurred opposite this clump of trees, but the regularity of the midge infestation was seriously interrupted by sprayed trees adjoining untreated trees. It should be noted that the treated trees in the remainder of the

experimental area were practically free from infested fruit, with an important exception which is discussed below, and that the sprayed trees near the clump of woods had a perceptible amount of injury to the fruit caused by the presence of the midge.

In general, the soil, which is mapped as Hudson silty clay loam, has a gentle northwest slope except for one marked feature; namely, a small ravine extends from near the southeastern corner of the orchard to near the northwest corner of the experimental portion, all of which is planted to pears. The bed of this depression averages from about eight to twelve feet below the general level of the remainder of the block, so trees growing on these slopes were more or less protected from the wind. Some of these treated trees were infested, but not so severely as were the trees on the south side near the woodland.

*Orchard No. 2.* The experimental plats of this planting consisted chiefly of Clapp Favorite pears set at least twenty years, and the trees were about 25 feet in height. The soil is mapped as Cossyunga gravelly loam. Owing to the size of the trees and the planting distances (16 feet), the lower branches occupied most of the intervening space. The orchard lies in a valley extending from southwest to northeast. The east side of the valley is rimmed by a low, narrow ridge which rises from 6 to 24 feet above the land occupied by the pears. The highest portion of this ridge is surmounted by a grove of cedars whose tops extend between 20 and 25 feet above the tops of the pear trees at a distance about 50 feet from the nearest ones. On the west side of the vale a steep, wooded hill towers to a height of more than 300 feet above the pears at a distance of about one-fourth mile. On the north and northeast a nearby house and numerous tall shade trees, distant between 150 and 300 feet from the pears, afford considerable protection; while to the south the gradual rising slopes are covered with forest trees at distances from 500 to 1000 feet from the experimental portions of the orchard. Thus it will be noted that all portions of the area are more or less sheltered.

Between 350 and 400 pear trees, for the most part in seven long rows, occupied all the cultivated land in the east half of the vale. The northerly half of these seven rows consisted of Clapp Favorite with a few Bartlett trees, while the southerly half were the variety Seckel. The test plats consisted of 168 trees in the northern portion. Here the efficiency of the treatment greatly reduced the number of midges on the sprayed trees and thus, to some extent, destroyed the continuity of the

midge population density between treated and untreated trees. However, the data clearly indicated that as regards the house and the tree covered ridge to the northeast, the distance from shelter was closely associated with variation in midge injury.

TABLE 1. INFLUENCE OF SHELTER TO PEAR MIDGE INJURY AT HUDSON, N. Y., DURING 1930 AND 1931

| Tree Number | Approximate Number Feet from Shelter | Average Percentage of Infestation | | Percentage of Total Infestation | |
|---|---|---|---|---|---|
| | | 1930 | 1931 | 1930 | 1931 |
| 1 | 50 | 50.6 | 5.9 | 30.5 | 48.0 |
| 2 | 70 | 42.3 | 3.3 | 25.5 | 26.8 |
| 3 | 90 | 36.1 | 2.4 | 21.8 | 19.6 |
| 4 | 100 | 13.2 | 0 | 8.0 | 0 |
| 5 | 130 | 9.4 | 0.2 | 5.7 | 1.6 |
| 6 | 150 | 6.2 | 0.5 | 3.7 | 4.1 |
| 7 | 170 | 7.9 | 0 | 4.8 | 0 |
| Total..... | | 165.7 | 12.3 | 100.00 | 100.1 |

The land in the western half of the vale was devoted to grapes and cultivated crops except that west of the experimental block just described there was a small block consisting of 28 Clapp Favorite pear trees of about the same size as in the remaining portion of the orchard. The rows of the west block extended at right angles to the long rows mentioned above. There were five rows with originally seven trees to the row. This west portion is separated from the east section by a space of approximately 40 feet. The most intense shelter was to the west as previously described, the outer limbs of the nearest pear trees being approximately 50 feet from the trunks of forest trees having heights between 50 and 60 feet. The branches of some of these deciduous trees (elms) had a spread toward the pears of from 15 to 20 feet. Moreover, in a distance of 600 feet the top of the forest towered to a height of 160 feet above the nearest pears, while at a distance of nearly one-fourth mile the bare top of the hill rose about 140 feet higher.

In 1930, twenty-three of these pear trees were sprayed with a mixture of molasses, nicotine sulfate and arsenate of lead, three trees being left untreated as checks. The treatment did not appreciably reduce the midge injury. Fortunately for the author, but not so fortunate for the grower, this did not disturb to any great extent the relative proportions of injured pears on the various trees, so an excellent opportunity was afforded to determine the decrease in percentage of midge-infested fruit as the distance from the source of shelter increased. The data from trees bearing the same number in the several rows were averaged. The results shown in Table 1.

During the spring of 1931 the same section was sprayed with lime-sulfur and nicotine which gave a high degree of control. Although the reduction in midge injury was marked, the effect of protection afforded by the woods and slope is noticeable. (Table 1.).

In order to facilitate comparison between the effect of shelter for the two seasons, the computations in the last two columns of Table 1 have been made, the object being to reduce the area of the two distributions to the same magnitude. It will be noted that while the character of the two distributions are considerably different, in neither case is there a linear relation between distance from shelter and midge injury. Although in each case the function is parabolic, nevertheless, two distinct types of parabolas are necessary to fit the distributions.

*Other Orchards.* Data from one additional pear orchard emphasize the relation already described, but is omitted due to space limitations. Furthermore, observations were made in a number of midge infested orchards in various parts of the state and it is interesting to note that in every infested planting examined the trees were sheltered either by topography, groups of trees or buildings, or by a combination of several or all of these factors. These findings seem to point to the conclusion that the results in the two orchards described are not isolated cases but are examples of a general effect produced by environmental complexes.

## THE ORIENTAL FRUIT MOTH IN NEW YORK

By P. J. PARROTT, *Geneva, N. Y.*

ABSTRACT

The importance of the oriental fruit moth (*Grapholitha molesta* Busck) to the peach industry of New York and the status of efforts with insecticides and parasites are briefly summarized. Since the outlook for a satisfactory control measure is considered none too promising, an appeal is made for a careful analysis of the present research program to determine the lines of attack which give most promise of a satisfactory solution.

The oriental fruit moth (*Grapholitha molesta* Busck) is now established in the Hudson Valley and in Western New York. These constitute the two important peach-growing areas in this state, and are rated among the famous peach districts of the country. Previous to the advent of this species the program of the peach industry with respect to pest control was a rather simple one, certainly so as compared with that of apples or pears. Because of the steady increase in the rate of infestation peach growers are in a crucial and perplexing situation, considering the losses sustained and the uncertainty of an early development of economical

methods of control. The history of the pest and an account of present conditions in the two areas are briefly summarized as matters of interest and record.

Occurrence of Insect in the Hudson Valley. In the Hudson Valley the infestation was first officially reported by Hartzell[1] and Mills in 1926. Since then the insect has spread gradually northward and may be found in the entire area between New York City and Albany. Here the planting of peaches represents approximately 639,000 trees.

The history of the pest in this region is doubtless much like that of many fruit districts in other states. Aside from passing interest in the original discovery, little attention was at first paid to the insect. It was not long, however, before infestations were discovered in other communities, and during succeeding years the pest continued to spread, cropping out in new places until the entire valley was well seeded.

The potential menace of the newcomer was appreciated to some extent by the more alert growers. While they did not relish the thought of its presence, they took it as inevitable and continued with little or no modification in their orchard operations. On the whole, there have been no material changes in spray practices to meet the needs of a new situation despite the flood of statistical information relative to the susceptibility of the pest to this or that newly proposed treatment. No appreciable number of trees have been cut down because of misgivings as to the future of the peach industry. On the other hand, a few new orchards have been set out, altho fear as to the ultimate outcome has unquestionably deterred any extensive planting of peaches. If there have been losses in the sale of fruit, the growers as a group have not made serious complaint; discretely so, since the consuming public has awakened to the fact that there is something wrong with peaches and to say anything more only makes matters worse. The problem of disposing of the fruit is perhaps not so great as that of other well-known peach districts because of the accessibility to local markets and the ease of disposing of the crop in the orchard by direct sales to truckers.

The Moth in Western New York. The moth was first discovered by Daniel[2] in western New York in a few orchards in the Lake Erie valley near the Pennsylvania line in 1926. In 1927 several orchards along the Niagara river were found to be infested. The pest was probably present in both of these areas at least a year before it was discovered. A survey of these areas led to the conclusion that the in-

[1]Albert Hartzell, Jour. Econ. Ent. Vol. 19, p. 868. 1926.
W. D. Mills, Jour. Econ. Ent. Vol. 19, p. 870. 1926.
[2]D. M. Daniel, Rural New Yorker, Vol. 85, p. 1543. 1926.

festation in Chautauqua county was due to the spread of the insect across the state line from Pennsylvania, while the occurrence of the pest in Niagara county is believed to have come about thru the spread of the moth from an older center of infestation in the Province of Ontario just across the Niagara river. Growers on this side were familiar by actual observations or reports from Canadian orchardists with the destructive nature of the insect, and with the realization of its presence in their plantings they became much alarmed and appealed to our Institution for assistance. Unlike the Hudson Valley, while a goodly percentage of the fruit finds its way to local markets, most of the crop is shipped in carload lots to the larger cities of the northeastern area of the country and there comes in direct competition with the products from the important peach-growing districts in other states. Fear of the possible harmful influence of infested fruits to retain a satisfactory market in which there is so much rivalry probably explains to a large degree the prompt appeals for assistance in this area as compared with the somewhat indifferent attitude manifested by the Hudson Valley growers.

Since the discovery of the pest in Niagara county in 1927, the species, thru natural spread and large shipments of infested peaches from southern states to our cities, towns, and villages, has become well seeded in the entire peach belt. The heart of the industry embraces an area about 100 miles long and 25 miles wide and is parallel with the shore of Lake Ontario. In the counties devoted to peach culture there are about 2,655,000 trees.

Three years ago we were unable to find the insect on the Station grounds or in commercial orchards in the immediate vicinity of Geneva. For three years, at least, it has not been difficult to find on the fruit stands infested fruits from southern states. Such has been the development of the pest in recent years that commercial injury was observed in our midst during the past summer. About Lewiston and Youngstown in the neighborhood of the original centers of infestation the injury to the peach crop varies from 7 to 18 per cent, while to the eastward where the pest has been established during recent years the damage to the fruit ranges from 3 to 25 per cent. Generally speaking, quinces in Niagara county are 100 per cent infested. From apples produced in this county, and which are confined in screened cages for the purpose of rearing the codling moth, one is not at all surprised to find an admixture of both insects.

SURVEY OF THE STATION'S ACTIVITIES AND COMMENTS. In the western New York peach district in particular, there is a persistent demand for a

practical method of combating this pest, and it is to this area that our workers are devoting the bulk of their efforts. The activities are presumably quite similar to those of other states, based as they are largely on the program formulated at the annual national conference of those primarily interested in the oriental fruit moth. The efforts are concerned chiefly with careful local surveys of the progress of the pest, breeding of the more important parasites and distributing them in key centers of new infestations, and the testing of insecticides.

THE SITUATION WITH SPRAY MIXTURES. With respect to insecticides, there is urgent need for a spray treatment that will appeal to peach growers, as did lime-sulfur in the late nineties or lubricating oil emulsion at a later period when the San Jose scale proved a similarly baffling problem to the entire fruit industry. Whatever the material, desirable requisites are that it shall be cheap, safe, and dependable, and that these qualities shall be easily demonstrable to growers. Otherwise, it may prove difficult to secure and hold their cooperation and support.

The spray procedures so far suggested are better characterized by their faults than by their virtues. They either mess up the fruits or deplete the orchardist's pocketbook, or both; and if some control is secured, the benefits obtained are not justified by the expense. The fact that a satisfactory material has not been devised does not mean that one will not ultimately be found. Failure to make strenuous effort to secure an insecticide that will meet the needs of the situation is, in my opinion, a great mistake. In the event that confidence in parasites slumps, a consideration well within the realm of probability, the development of a satisfactory spray program would afford the peach growers at least one prop on which to lean.

DISTRIBUTION OF PARASITES. At present the work with parasites commands major attention and appeals most strongly to growers. The energies of a small group of workers are taxed to the utmost in breeding and distributing the more promising species under the stimulus of expert opinion that this is the most hopeful means of ultimately bringing the peach moth under control. The activities point to some definite accomplishments. It has been proved that Macrocentrus overwinters safely and has now become established in orchards where previous to its introduction there was no evidence of its presence. Each year distributions are made in new centers of infestation. While the breeding and distribution of parasites has thus far been regarded as a desirable type of activity as an emergency measure, since growers are clamoring for such assistance, we have nevertheless made clear to the peach industry that we have no assurance that these efforts

alone will lead to a successful outcome. However, growers are pinning their hopes on parasites. Personally, I hold mental reservations regarding the future of the enterprise, particularly if no more is done than merely distributing parasites, a few thousand *Macrocentrus* and a hundred or so of this and that species, which must be insignificant in number compared to those produced under natural conditions and which are already in the plantings where colonization is being attempted. If parasitic work is to become one of the functions of the Experiment Station and is going to hold its own as a definite line of effort, then more emphasis needs to be placed on the research and experimental aspects of the problem than has so far been evident. The stress until now has been placed on the rearing of the largest possible number of certain species with little definite knowledge as to the total required to produce a desired effect and with small understanding of the significance of the rate of parasitism even tho increases are noted. High rates of parasitism may be observed with many insect pests, but unless the host is more or less permanently held to a low level of destructiveness, parasitism does not generally afford grounds for optimism; for, as often as not, parasitism may be exceedingly high and yet the host species may succeed in bringing desolation to a crop. What evidence is there to support the opinion that *Macrocentrus* has potentialities not possessed by many other common parasites that it should so monopolize attention as to exclude other considerations that may be more vital? Perhaps it is not amiss to suggest that the conclusions drawn from some of the studies with this parasite, or at least the implications from such efforts which are widely quoted, may be open to question because of the failure to consider other factors in evaluating the results. Unless workers have a thoro understanding of the many complications which inhere in such undertakings, there is danger of increasing and unscientific promotion of the method of biological control which may do incalculable harm.

And so with respect to future efforts, the need is for the workers in this field to keep the goal definitely in mind. The principle involved in the handling of *Macrocentrus* is the mass rearing and mass distribution of a parasite thought by some to be an indigenous species. It remains to be determined if this can be successfully applied as a means to combat the oriental fruit moth. Searching for new parasites, native or exotic, and a study of the influence of spray and dust practices are worth consideration. Efforts of this character may not only shed some light on the control of the pest, but they may also make clear the desirability of continuing similar efforts on this and other projects.

INSECTICIDES VERSUS PARASITES. And finally, with respect to the control of the pest, there are to all appearances two schools of thought and the issue is between insecticides and parasites. Each group takes a definite position and, because of the difficulties that inhere in the problem, each has some justification for its stand. Personally, I hold no prejudices for the one or the other; for it matters little by whom the work is being done, providing it is well done. However, as one charged with the responsibility of directing entomological efforts, one in my capacity must perforce take stock of what has been done and is being done. Since neither group can point to any definite accomplishment that meets the needs of the practical grower, it is hard to avoid wishful thinking. However, there is extreme need that one or the other or both groups find, as speedily as possible, a solution of the problem. With such a consummation growers will rejoice that their burdens have been lightened and entomologists will experience a feeling of relief in being rid of the necessity of resorting to plausible speech and evasive writing.

## PRESENT STATUS OF ORIENTAL FRUIT MOTH PARASITE INVESTIGATIONS

By H. W. ALLEN, *U. S. Bureau of Entomology, Moorestown, N. J.*

ABSTRACT

The oriental fruit moth (*Laspeyresia molesta*) is attacked by a large number of parasites in the United States, and also in Europe, Australia and Japan. Because of the importance of parasitic attack and the lack of effective artificial controls, it seems probable that work with the parasites will help to control the pest. This article mentions certain possibilities both in the matter of importing foreign species and work with indigenous species and reviews the work which has been done.

During the past few years the oriental fruit moth has become one of the most troublesome insect pests of the peach in the eastern part of the United States. It has caused very severe damage to the crop in many localities, and as yet no generally effective artificial control measures have been devised. Fortunately this insect has proven to be susceptible to attack by native parasites in many sections in which it has become established. The extent of this parasitism is not uniform and has not usually been significant in its manifestations during the early stages of invasion of the pest. There is good reason to believe, however, that by studying the reactions of the parasites with their host and with the climatic, physiographic, and biological features of their environment, means may be found for utilizing them more effectively as important factors in the control of the fruit moth.

In considering the biological control of the fruit moth, it should be borne in mind that its effectual control differs in one important respect from that of foliage-feeding pests such as the gipsy moth. In the case of defoliating insects, unless the biological potential is unusually high, the destruction of 90 per cent may so reduce their numbers that the feeding of the few remaining will cause no appreciable damage in the forest, and an effectual control will be obtained. In the case of a fruit-infesting insect the situation is different. Each surviving worm will destroy a fruit, and even a 10 per cent survival may be sufficient to reduce seriously the value of the crop in a market which demands clean fruit. However, it can not be denied that a factor such as biological control which, in the absence of effective artificial controls, has demonstrated its power to reduce an infestation of 50 to 70 per cent or more of the fruit to 10 per cent or even less is decidedly to the advantage of the peach-growing industry, particularly since this control operates automatically and at no direct expense to the grower.

There are four different ways which offer possibilities for productive effort with the parasites of the fruit moth. These are (1) importation of foreign parasites not occurring in the United States, (2) distribution of indigenous species from sections in which they are abundant into sections in which they are not known to occur, (3) mass rearing and liberation of easily bred parasites to supplement native stock at critical periods, and (4) development of farm practice by which existing stocks of parasites may be conserved and increased. In this paper an attempt will be made to discuss briefly the possibilities of the four avenues mentioned above, and what has already been accomplished in each.

IMPORTATION OF FOREIGN PARASITES. It seems quite likely that among the very considerable number of parasites already known in various parts of the world some will be found which will strongly supplement our native species. Our efforts are directed particularly towards the introduction of parasites of the egg and cocoon stages, which at present are not so heavily parasitized as the twig-infesting larvae, and the introduction of species which will establish themselves in sections where our native parasites have not as yet proved effective.

The possibilities of foreign fruit moth parasites were first investigated in Europe where Mr. G. J. Haeussler of the oriental fruit moth parasite investigations has been working since 1929, and from whose investigations the following information has been obtained. The fruit moth was presumably introduced into southern Europe from the United States at about the close of the World War. At the present time a number of parasites have commenced to attack it in that area, but,

except for certain species of cocoon parasites, their effectiveness is low. The total parasitism of twig-infesting larvae is usually less than 5 per cent. The principal species include two ichneumonids, *Pristomerus vulnerator* (Panz.) and *Trichomma enecator* (Rossi), the tachinid *Zenillia roseanae* (B. & B.), and the braconid *Ascogaster quadridentatus* (Wesm.). In artificially exposed cocoons as high as 70 per cent parasitism has been obtained. The principal species involved are *Dibrachys boucheanus* (Ratz.), *Itoplectis alternans* (Grav.), and *Hemiteles areator* (Grav.), the last two not being present in the United States. Unfortunately all of these cocoon parasites are secondaries at times; and although their effect in Europe on this pest is beneficial, on account of this hyperparasitism they can not be considered for importation. The European work has been limited to the heavily infested strip along the Mediterranean including southeastern France and northwestern Italy. It has been conducted during the past three seasons, and has practically exhausted the possibilities for parasites in that area, at least for the present.

Among the European parasites of the twig-infesting larvae *Pristomerus vulnerator* seems the most promising. Considerable numbers have been imported and colonies released in three widely separated localities. Small recoveries have been obtained from one of these. Six other European species have been imported and released, including *Trichomma enecator*, a small braconid, *Apanteles anarsiae* F. & A., and three tachinids, *Zenillia roseanae*, *Arrhinomyia tragica* Meig., and *Actia tibialis* Rond. *Ascogaster quadridentatus*, which attacks the egg and emerges from the cocoon, is a better parasite of the fruit moth in southern Europe than its American counterpart *A. carpocapsae* Cush. It has been imported and increased by insectary breeding to large numbers this season, and 37,240 adults have been liberated in two widely separated sections. It is as yet too early to report results. The species has a potential possibility of strongly supplementing indigenous American parasites by attacking the larvae infesting fruit, and as such would be a valuable addition to our list. Only one egg parasite has been imported, *Trichogramma euproctidis* Gir., which has just recently been received and has not as yet been released.

The region about Sydney, New South Wales, Australia, has been known to be infested by the oriental fruit moth for many years. Froggatt dated the infestation back to 1909, and considered the insect an introduction. The sending of Mr. R. W. Burrell, of the Japanese Beetle Project, to Australia in 1930 provided an opportunity for investigating the possibilities of oriental fruit moth parasites in that area, and permitted the gathering of the information given below. At present the

fruit moth infestation about Sydney is low, although no special artificial or cultural control is practiced, and the parasitism is moderately high. In other isolated peach-growing districts that have been investigated, particularly the Mooroopna district in Victoria, the infestation is much heavier, and although parasites occur, there are not so many species or as high parasitism as in the older infested district about Sydney. The four principal species so far reared are a large, stout ichneumonid, *Gambrus stokesii* Cam., a true pupal parasite, *Antrocephalus pomonellae* Cam. and two much smaller parasites of the cocoon stage, the bethylid *Perisierola* sp., and a Dibrachys. One of these, the species of *Perisierola*, has recently been successfully imported and is being held over until spring. Plans are under way for rearing and importing the two other principal parasites found there. These are *Gambrus stokesii* and *Antrocephalus pomonellae*. These are all primary parasites of the cocoon stage and offer the possibility of materially strengthening that rather weak link in the series of North American parasites of the oriental fruit moth. The Dibrachys will not be imported because of the strong tendency of the whole group towards secondary parasitism. Owing to the fact that Mr. Burrell will soon be transferred from Australia to other work of the Japanese Beetle Project, the possibilities of that area can be, for the present, only partially realized.

The evidence at present available indicates that Japan or the near-by Asiatic mainland may be the original home of the fruit moth. Seventeen species of parasites have been reported from one prefecture south of Yokohama, and others have been reared from other places in the Japanese Islands and from Chosen (Korea). Little has as yet been done towards obtaining introduction of valuable species from this region, though plans are under way for undertaking work in Japan in 1932.

Distributing Indigenous Species. The present picture of geographic distribution of the fruit moth and its North American parasites is one in which the host is widely distributed and destructive over most of the area where peaches are grown east of the Mississippi River. Within this large area many species of parasites, over 50 of which have been recorded, appear to occupy more restricted ranges, with only a few occurring as parasites of the fruit moth over the whole area occupied by the host. The reasons for this may be (1) that the parasite species has never penetrated to certain portions of the infested area, (2) that local strains accepting the peach moth have not as yet had sufficient time to develop from the general population, and (3) that local environmental conditions, such for instance as lack of suitable alternate

hosts, serve to exclude the parasite from certain areas. In the first two instances it may be possible to hasten the process of stabilization which will ultimately take place between the host, its parasites, and the environment, by distributing the various parasite species from centers of abundance into those sections in which they are not known to occur.

At present *M. ancylivorus* Roh. seems to offer the greatest possibility for work of this nature. Previous to the work which has been under way since 1929 it was known as a parasite of the fruit moth only in a rather narrow coastal strip from southern Connecticut to southern Virginia. Within this area it had clearly demonstrated its value, often destroying 90 per cent or more of the twig-infesting larvae, and in New Jersey, particularly, being mainly responsible for a very decided reduction in fruit infestation in the principal mid-season varieties.

During the past three seasons a large part of the effort with native parasites has been expended on a program of rearing *M. ancylivorus* and releasing it in distant centers. This material has practically all been collected from or reared in Burlington County, N. J., where the parasite is particularly abundant and the facilities for such work excellent. A total of 75,700 adult parasites have been shipped for releasement. For each adult shipped, approximately 8 infested peach twigs or strawberry leaves were collected and cared for until emergence of the parasites. The Moorestown, N. J., station has also worked in close cooperation with several states interested in programs of introducing the same species, helping in the collecting of an additional 656,000 parasitized larvae from the southern New Jersey area. Since these liberations were made, *M. ancylivorus* has been recovered from practically every important peach-growing center in which it has been liberated. There has as yet not been a sufficient lapse of time to indicate its ability to persist and to increase and spread in all these centers. This year our most encouraging records were obtained from recovery collections made in northern Connecticut, along the lake shores of New York and Ohio, and in certain sections of central Ohio and western Indiana, in which the parasitism by *M. ancylivorus* exceeded that of all other species and approximated the numbers obtained in the New Jersey center. However, it should be explained that the results were considerably confused by large additional liberations of adults made during the present season. Outside the areas mentioned, our recovery collections have failed to indicate results as distinctly favorable.

There is a possibility that beneficial results might be obtained in some areas from similar work with each of the other parasites that have proved abundant and useful in any restricted locality. This would

include *Glypta rufiscutellaris* Cress., *Macrocentrus delicatus* Cress., *Macrocentrus* sp., *Pristomerus ocellatus* Cush., Trichogramma of the various races, and possibly some other species. In 1931 four liberations of *G. rufiscutellaris* and three of *Pristomerus ocellatus* were made in centers in which they were not known to occur. Pristomerus was subsequently recovered from two colony localities in Tennessee, Kingston and Harriman; Glypta, from Commerce, Ga.

Unfortunately a number of the best parasites of the cocoon stage are habitually secondaries as well as primaries, and for this reason should be handled with great caution and not moved from one section to another until all uncertainty as to their possible harmful influence in the new region has been definitely removed. Species in this group include *Itoplectis conquisitor* Say, *Dibrachys boucheanus* Ratz., *Hemiteles tenellus* Say, *Eurytoma* sp., and several others.

Mass Liberations. In the work of mass breeding and liberation of parasites already occurring in a given region, *Trichogramma minutum* Riley would seem to offer possibilities since it can be so easily produced in enormous numbers and is at times a valuable parasite of the fruit moth. However, the efforts that have been directed to this end in Burlington County, N. J., have had rather unsatisfactory results, as will be explained later. Other species that might be considered for such work are three forms of Macrocentrus, *Glypta rufiscutellaris*, *Ascogaster quadridentatus*, *Itoplectis conquisitor*, and *Dibrachys boucheanus*, all of which are easily bred in confinement. There would not necessarily be objections to local liberations of the last two in sections where they already occur, if the end result in pests destroyed exceeded their effect as secondaries.

At Moorestown, N. J., during the past two years experiments have been conducted to demonstrate the economic feasibility of liberating large numbers of Trichogramma in orchards at such a time as to permit high parasitism of the eggs of the generation of larvae entering the fruit and thereby to effect protection of the crop. These liberations have been made under the most favorable conditions obtainable and have been checked principally for evidence of decrease in fruit infestation obtained. In 16 experiments conducted during the two years there have been 12 decreases in infestation and 4 increases, in liberation blocks over corresponding check blocks. The average infestation of liberation blocks was 45.3 per cent in 1930 and 21.8 per cent in 1931, and the average decrease from check blocks 6.8 per cent in 1930, and 3.0 per cent in 1931. This seems to indicate that in the area in which these experiments were conducted, and with the methods used, the liber-

ation of this parasite does not produce economic results significant enough to warrant such liberations. It at least suggests that more experimental work should be done to develop the practical possibilities before large-scale production and liberation are undertaken.

RELATION OF FARM PRACTICE TO EFFECTIVENESS OF PARASITES. There are evidently many ways in which agricultural operations serve to alter the population of parasites present in a given area. Driggers (1) has pointed out how applications of talc dust made to kill young larvae may be relatively ineffective through the associated action in inhibiting Trichogramma. It is known that in the southern New Jersey area second-year strawberry beds are plowed under immediately following the removal of the crop, thus destroying vast numbers of *M. ancylivorus* at a season when the parasite is most valuable as a control of the fruit moth. It is known that not many *M. ancylivorus* winter over in the fruit moth larvae, the numbers in this host being exceeded in the southern New Jersey area by those wintering over in the strawberry leaf roller, and possibly in other hosts. It is possible that the dominance of the parasite in this region may be largely dependent upon the circumstance of the extensive growing of strawberries in relatively close association with peaches. Little work has been done on this and related problems, though there can be no question but what carefully conducted studies will enable us to understand the limitations of various species and will probably suggest methods by which their usefulness may be extended, by following certain cultural methods.

SUMMARY. Owing to the severe damage caused by the oriental fruit moth and to the fact that generally effective artificial control methods have not as yet been devised, considerable attention has been given to the parasites which have in certain areas proved capable of at least partially controlling the pest.

Parasites of the pest are known to occur in Europe, Australia, and Japan. Work has been under way with the European parasites since 1929. Eight species have been imported from that area, seven liberated, and to date one has been recovered. One species has been imported from Australia, and it is hoped that two other important species will be received this winter. Investigations of the possibility of obtaining valuable species from Japan will start in 1932.

It is considered that there is a possibility of doing valuable work in distributing indigenous species from centers where they are abundant to localities in which they are not known to occur. During the past three years a large number of *M. ancylivorus* have been reared and distributed in all heavily infested centers. Recoveries have been made from nearly

all of these centers, although the evidence now available points to favorable results only in more restricted areas.

Mass liberations have been chiefly concerned with *Trichogramma minutum*, from which rather unfavorable results have been obtained in southern New Jersey.

In conclusion it should be pointed out that considerable work has been done with the parasites of the fruit moth, most of which is too recent to permit a reliable estimation of results. It seems unlikely that a very considerable portion of the various leads attempted will yield valuable results, but success with only a portion of them, sufficient to bring about a condition of the host which now exists in New Jersey, would go far towards reducing the importance of the oriental fruit moth as a pest.

LITERATURE CITED

1. DRIGGERS, B. F. Jour. Econ. Ent. 23: 209–215 (1930).

## ORIENTAL FRUIT MOTH PARASITES IN MARYLAND

By H. S. MCCONNELL, *Md. Agr. Exp. Station, College Park, Md.*

ABSTRACT

List of Oriental fruit moth (*Laspeyresia molesta*) parasites recorded by Maryland Experiment Station workers, with notes on their relative importance and distribution in the State.

The first records of Oriental fruit moth parasites in Maryland were published in 1917 (1) by Garman, when *Trichogramma minutum* Riley and *Macrocentrus* sp. were reported. The following year the same author reported (2) *Trichogramma minutum* Riley, *Macrocentrus* sp., *Ascogaster carpocapsae*, Vier, *Lixophaga variabilis* Coq., *Nemorilla phycitae*, LeB., *Leskiomima tenera* Weid., and a *Eupelminae* as primary parasites; and *Dibrachys boucheanus* Ratz., and *Eurytoma* sp. as secondary parasites. A number of the specimens of *Macrocentrus* above reported, are still in the Maryland Experiment Station collection and of those that can be positively identified as bred by Garman in 1917–18 are *Macrocentrus ancylivorus*, as the species is understood now. This fact is of considerable interest since later breeding records for the same locality show that approximately 20% of the *Macrocentrus* specimens secured are *Macrocentrus delicatus* Cress. Since *Macrocentrus delicatus* Cress. is a well established species, it would seem that it has only recently turned its attention toward the oriental fruit moth as a host.

During the past five or six years, more and more attention has been given to biological control of the oriental fruit moth, since artificial measures have been ineffective so far. Biological control in Maryland to date has been limited to an attempt to establish *Macrocentrus ancylivorus* Rohw. in all peach growing sections of the state. With this purpose in mind it was necessary to make a comprehensive survey of the oriental fruit moth parasites. The results of this survey show that Maryland has a fair share of oriental fruit moth parasites and that the important species are well distributed over the state. *Macrocentrus ancylivorus*, the principle species, has been found present in all parts of the state except the western portion which is the area most recently infested by the oriental fruit moth.

Since there has been no complete list of the oriental fruit moth parasites of Maryland published, those secured by Maryland Experiment Station workers are brought together here without reference to their relative importance.

EGG PARASITES

Trichogramma minutum Riley

LARVAL PARASITES

Macrocentrus ancylivorus Rohw.
Macrocentrus delicatus Cress.
Glypta rufiscutellaris Cress.
Pristomeris ocellatus Cush.
Hoplocryptus incertulus D. T.
Ascogaster carpocapsae Vier.
Microbracon gelechiae Ashm.
Microbracon mellitor Say
Microbracon politiventris Cush.
Microbracon sp.
Epiurus indigator Cress.
Apanteles harti Cush.
Calliephialtes benefactor Cush.
Phanerotoma tibialis Hald.
Aenoplex betulaecola Ashm.
Eubadizon sp.
Eupelmus limnariae How.
Eupelmus sp.
Bassus cinctus Cress.
Lixophaga variabilis Coq.
Nemorilla phycitae LeB.
Leskiomima tenera Wied.

PUPAL PARASITES

Centeterus ineptifrons Gahan
Ephialtes equalis Prov.

SECONDARY PARASITES

Dibrachys boucheanus Ratz.
Eupelmus cyanoceps, var. amicus Gir.
Arachnophaga N. Sp.

An extensive survey has also been made of the parasites of the strawberry leafroller, *Ancylis comptana* Froel., and a less thorough one of the ragweed borer, *Epiblema strenuana* Walk., to determine to what extent they have parasites in common with the oriental fruit moth. The most important species so far secured from the ragweed borer are *Macrocentrus delicatus* Cress. and *Glypta rufiscutellaris* Cress. A number of other species have been secured in small numbers, but *Lixophaga variabilis* Coq. is the only one common to both hosts.

The parasites of the strawberry leafroller have been found to be somewhat more diverse than those of the oriental fruit moth, but the populations of the two hosts have very little in common. From about 3,000 specimens of strawberry leafroller larvae and pupae that were

isolated in individual vials, the only parasites secured common to both hosts are: *Microbracon gelechiae* Ashm., *Hoplocryptus incertulus* D. T., *Lixophaga variabilis* Coq., and *Macrocentrus ancylivorus* Rohw. Only two specimens of *Macrocentrus* were secured, and those from a locality almost devoid of peach plantings. This data was all secured from the summer generations of the leafrollers. No records have been made on the overwintering individuals. These records indicate the ragweed borer is an important host for certain oriental fruit moth parasites, while the strawberry leafroller is negligible as a host

During the summer of 1930, six colonies of *Macrocentrus ancylivorus* Rohw. were liberated in peach orchards in Maryland. Three of these were furnished by the Bureau of Entomology, and three bred at the Maryland Experimental Station. The three Bureau of Entomology colonies were liberated at Berlin, Cordova and Hancock; and the three Experimental Station colonies at Glenburnie, Bel Air, and Hancock. Twig collections made immediately before colonies were located at Glenburnie, Bel Air and Hancock indicated that *Macrocentrus* was not present at Bel Air and Hancock, but was present at Glenburnie. Twig collections made about 8 days after liberations indicated *Macrocentrus ancylivorus* had become established at Bel Air, but no specimens were secured from the Hancock liberation. No twig collections were made in 1930 where the three Bureau of Entomology liberations were made.

During 1931, five colonies were furnished by the Bureau of Entomology and all liberated in the western part of the state at the following places: Mt. Airy one colony; Frederick one colony; and Hancock three colonies, each in a different orchard. Twig collections made about 10 days after parasites were liberated and in addition collections made in Hancock orchards where 1930 colonies were liberated, indicated establishments in three orchards at Hancock as follows: the two 1930 liberations and one 1931 liberation.

To date, *Macrocentrus ancylivorus* Rohw. has been the most important parasite in all parts of the state, except the western mountain section, where *Glypta rufiscutellaris* is the most abundant species. In the middle portion of the state *Macrocentrus delicatus* Cress. is the second important species, while in the eastern part of the state it assumes a minor roll. *Trichogramma minutum* has been important in various parts of the state under certain conditions, especially where there is a heavy deposition of eggs on apple or quince.

It has been impossible to evaluate the practical value of parasites in protecting peaches from the attack of the oriental fruit moth. Cases have been observed where larvae in twigs have been parasitized to the

extent of 90% by August 1, but despite this high degree of parasitism 50% or more of Elbertas and varieties maturing later have been infested.

REFERENCES

1. Maryland Agriculture Experiment Station Bulletin No. 209, 1917.
2. Maryland Agriculture Experiment Station Bulletin No. 223, 1918.

## BEHAVIOR OF TRICHOGRAMMA IN FIELD LIBERATIONS

By J. C. SCHREAD

ABSTRACT

Trichogramma (*T. minutum*) liberated in a block of 121 trees without parasites dispersed in all directions and resulted in 50 per cent parasitism. One other orchard with low parasitism increased 53 per cent after a single liberation. A third orchard having high natural parasitism was not increased by large liberations. The parasite flew 24 feet under laboratory conditions.

Due to the trend within the past few years toward large-scale mass production and liberation of Trichogramma, considerable interest has been aroused regarding the dispersal ability of the parasite. There seems to be two major opinions concerning this subject: one group believing the parasite does not fly to any great extent (if at all), therefore depending entirely on air currents for dispersal from points of liberation, while the second group feels confident that Trichogramma is capable of flying from place to place and when aided by wind and air currents will travel for some distance. We are in sympathy with the second group, and herewith submit one season's laboratory and field experiments on this subject. It is not our intention to imply that the results of our work are conclusive. We merely wish to present the information obtained as indicative of what might be expected under similar conditions.

We have observed in cultivated peach orchards bordering woodland, brushland, pastures and meadow land, that the per cent of parasitized peach moth eggs in the early part of the season is, as a rule, much higher in the first row or two of peach trees nearest these outside areas. As the season progresses, the parasitism becomes more general throughout the orchard. It seems fair to assume that such a condition is partially due to the migration of Trichogramma into the orchard from outside areas where they survived the winter in native host eggs. There is no certainty that all peach moth egg parasitism in the early part of the season may be accounted for in this way, but a good part of it is due to this one factor as the amount of native host material in which the parasite could overwinter is greater outside a cultivated orchard than in it.

Taking these factors into consideration, it was thought advisable to make a few observations on the dispersal of Trichogramma from a standpoint of flight, both under laboratory and field conditions. In the laboratory we ascertained that Trichogramma flew for distances varying from five feet up to 24 feet. The procedure followed to obtain these results is as follows:

Several hundred Trichogramma were liberated in a dark room five feet from an electric bulb. Three minutes after liberation a number of Trichogramma were seen crawling around on a piece of white cardboard directly behind the light. A second trial was made in a dark cellar where the temperature was 57° F. There were no air currents and the humidity was over 70 per cent. At a point 24 feet distant from an electric light, approximately 400 Trichogramma were liberated. One female flew the distance of 24 feet in two minutes and five minutes after her appearance was recorded, a male appeared on the white cardboard back of the light. Twenty minutes after the parasites were liberated, one more male and two females alighted on the cardboard, making a total of two males and three females having flown a distance of 24 feet in 20 minutes.

FIELD EXPERIMENTS. The orchard in which the major part of the field work was carried on contained 300 twelve-year old trees, most of which were in good bearing condition. The trees were planted 18 feet apart with from six inches to five feet between the tips of the branches. The orchard received no cultivation during the 1931 season after blooming time, which resulted in early hardening off of the trees. There were very few peach moths in the orchard during the early part of the season, and practically none during July and August.

After a chance collection of peach moth eggs was undertaken without success, an experiment was planned to study the dispersal of Trichogramma from a single point of liberation to outlying points in four different directions. A block of 121 trees was staked off in the center of the orchard and from this a cross of 21 trees, through its center, was selected for specific observations. From this cross, data was secured and used in figuring the probable results of Trichogramma dispersal throughout the block.

Twenty-one peach leaves having a total of 656 peach moth eggs were distributed in the 21 trees by fastening, with one or two toothpicks, the leaves on which the eggs had been deposited to the underside of large peach leaves on the trees. Three days later all of the eggs were examined and found to be unparasitized. A check on this result was conducted in another portion of the orchard by exposing peach moth eggs

as before. No parasitism was recorded. We considered these tests as sufficient evidence of a probable nonexistence of Trichogramma in the vicinity of the blocks under observation.

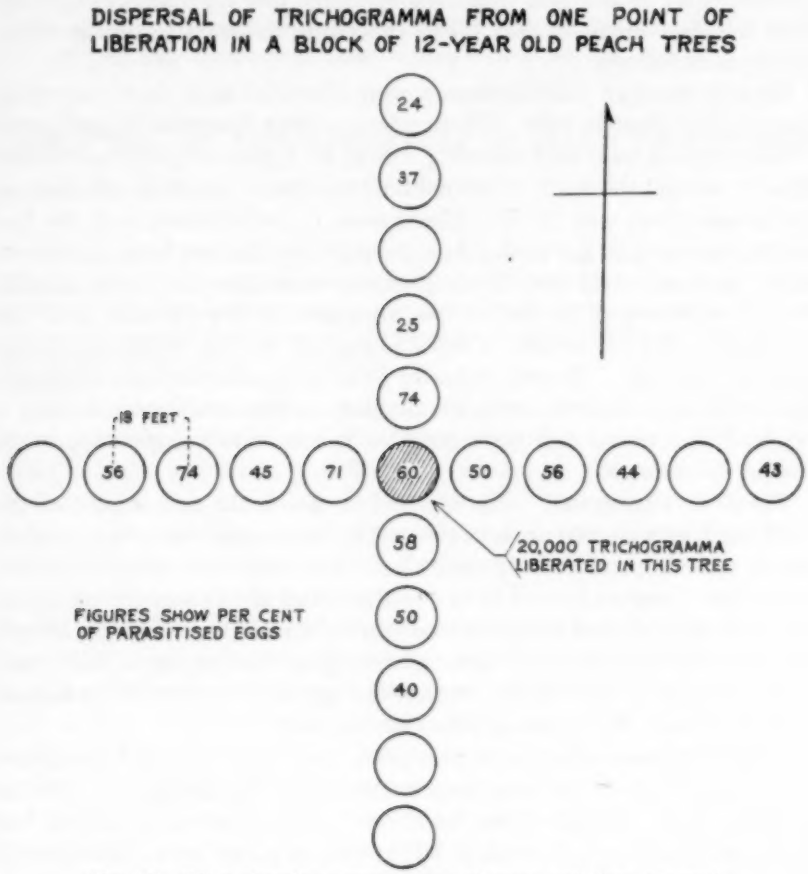



FIG. 25.—Plan showing arrangement of trees and data secured.

Forty peach moths were caged in a single flour sack in each one of the 21 trees comprising the cross. Three days later the sacks were transferred to 21 different branches on the same trees. At the same time ten bags containing sections of Trichogramma parasitized grain moth eggs totalling approximately 20,000 eggs, from which the parasites were emerging, were hung in the center tree of the group of 21. The second group of bagged branches were uncovered after three days. Eggs were found on all the branches with the exception of five branches

from each of the two lots. Of the remaining 32 branches having peach moth eggs, all but three had varying percentages of parasitized eggs.

The average wind velocity from the day the parasites were liberated until all eggs were examined was 6.6 miles per hour, blowing from a general westerly direction. However, it shifted to the east twice during the six days, for a total of nine hours, resulting in a 93 per cent westerly wind and a seven per cent easterly wind during the time of the experiment. There was no precipitation during the six days. The maximum wind velocity was 10.8 miles per hour, blowing from the southwest, and the minimum, 4.6 miles per hour, blowing from the north. The average temperature was 73° F. and the relative humidity 76 per cent.

In spite of the fact that the greater part of the prevailing wind was from a general westerly direction, the average parasitism of 49.5 per cent in the western half of the block was higher than the average of 43 per cent for the eastern half of the block. There was not such a great difference between the northern half of the block, with an average parasitism of 47 per cent, and the southern half of the block, with an average parasitism of 45.5 per cent. The average parasitism for the cross of 21 trees was 50 per cent. It is readily seen, however, that the general westerly wind did not account for a higher parasitism in the eastern half of the block; neither did it interfere with the spread of the parasite into the western half, as the average parasitism here is higher than in any other section of the block.

From a purely dispersal standpoint, it can be seen that Trichogramma spread throughout the block, and as the per cent of parasitized eggs in the outlying trees is very nearly as high as in those near the center of the block, the spread was quite general in all directions, regardless of air currents. Furthermore, it is fair to assume the parasite continued its spread some distance beyond the confines of the experiment. Whether or not this spread is entirely due to the flight of the parasite, or entirely due to air currents, is debatable. Nevertheless, the results seem to point toward a combination of the two, slightly favoring the former.

Several other experiments were conducted during the season in widely separated orchards to determine if it were possible to increase the rate of egg parasitism much above that obtained in the experiment just discussed. In one orchard where the natural parasitism was 44 per cent, peach moths were caged in flour sacks (as described) at four different times. Trichogramma were liberated in each tree in the orchard during the exposure of the peach moth eggs. The rates of parasitism for the four trials were: 46, 41, 42 and 45 per cent, averaging 43.5 per cent. Two of these trials were conducted during the height of the second

brood of peach moths, and two during the height of the third brood of peach moths. Between the second and third brood the parasitism dropped to 27 per cent, but immediately went up again when the third brood of moths appeared and more Trichogramma were liberated. In still another orchard, where the natural parasitism was but five per cent up until late in the season, the liberation of 200 Trichogramma in each of 240 trees in the latter part of August forced the parasitism to 58 per cent, an increase of 53 per cent in ten days. In a fourth orchard,where apparently no parasitism existed, the bagging of peach moths and the liberation of a few hundred parasites in each tree resulted in a 48.5 per cent parasitism.

Taking all of these experiments into consideration, we believe 40–50 per cent parasitism of peach moth eggs about the limit to expect in Connecticut. If the natural parasitism is within or near these limits, it would be futile to liberate Trichogramma with the intention of profitably increasing the percentage of parasitism already existing. However, when the existing parasitism is below normal at a time when host material is most abundant, it may be brought up to normal by mass liberation of Trichogramma.

PARASITISM BEFORE AND AFTER TRICHOGRAMMA LIBERATION

| | Egg Count | Per cent Parasitism |
|---|---|---|
| Before | 656 | 0 |
| Three days after | 321 | 48 |
| Six days after | 356 | 52 |

## THE RESULTS FROM TWO YEARS' EXPERIMENTS IN MASS LIBERATIONS OF *TRICHOGRAMMA MINUTUM* AGAINST THE ORIENTAL FRUIT MOTH

By H. W. ALLEN and A. J. WARREN, *U. S. Bureau of Entomology, Moorestown, N. J.*

ABSTRACT

During 1930 and 1931, sixteen experimental liberations of *Trichogramma minutum* Riley were made in blocks of late peaches in New Jersey. Reductions of fruit infestation in the liberation blocks, as compared with their respective checks, were observed during both seasons. The reductions, however, were so small as to be of insignificant economic importance.

The work on *Trichogramma minutum* Riley at Moorestown, New Jersey, during the past two years has been chiefly concerned with the problem of determining whether mass liberations would appreciably reduce the oriental fruit moth infestation of late peaches.

The trend of the fruit-moth infestation in this section is normally lateral or downward for the first two broods, under the influence of the

very high parasitism of the twig-infesting larvae, followed by low infestations of varieties which ripen at the same time as, or previous to, Elberta. In the later broods, which pass directly from egg to fruit and so escape heavy parasitism, the increase is rapid, and a heavy infestation of the late varieties results. *Trichogramma minutum* is usually present in all orchards throughout the season, but its abundance fluctuates widely and it possesses a strong tendency towards spotty distribution. Much effort has been expended in making our experimental liberations under as favorable conditions as could be obtained, and it is probable that these were more favorable than would exist under larger scale control operations.

During 1930, liberations were made in six blocks, including the principal mid-season variety, Elberta, and the more important late varieties, including Roberta, Fox Seedling, Iron Mountain, and Krummel. A local yellow strain of Trichogramma, originally obtained from the fruit moth, was used for liberations. All liberations were at the rate of approximately 55,000 per acre. A small section of card bearing 500 unemerged parasites, inserted in a paraffined manila envelope, comprised the liberation unit. One of these was pinned to a small limb in the top of each tree in the liberation block. Our aim in making the liberation was to provide large numbers of adults evenly distributed through the orchard at a time suitable for the destruction of a maximum number of the host eggs, which, if not destroyed, would produce the worms entering the ripening fruit. From studies of seasonal cycles previously made, it seemed that for each variety about 30 days before picking would be the best time for liberation. In each case a portion of the block was selected for making the liberation, and an adjacent portion for checking observations and results.

The emergence of parasites from liberated stock was found to range from 54.6 to 90.7 per cent and to average 79.6. No evidence was obtained of predators destroying parasites previous to emergence, though this would have been possible from the type of container used. An attempt was made to determine the amount of parasitism in liberation and check plots both before and after liberation. Three observations were made for each variety, the first being made immediately preceding the liberation, the second 15 days after liberation, and the third 25 days following the liberation. Observations were based on the parasitism obtained in small numbers of fresh eggs planted at selected intervals. A rather low percentage of parasitism was obtained in both liberation blocks and their checks. No definite trend was noted.

A sample of approximately 200 peaches was selected at picking time

FIG. 26.—Map of Krummel Orchard I. c1 and c2 = control blocks; exp. = liberation blocks. Rings and dots indicate trees, and the black numbered dots those trees selected for making observations of parasitism.

from each liberation block and from each check. These were cut and the record of infestation was obtained. The results are given in Table 1.

TABLE 1. THE PERCENTAGE OF INFESTATION IN FRUIT SAMPLES FROM EXPERIMENTAL PLOTS FOLLOWING LIBERATION OF *Trichogramma minutum* IN 1930

| Variety | Check | | Liberation | | Per cent Increase or Decrease Compared with Check |
|---|---|---|---|---|---|
| | Number in Sample | Per cent Infested | Number in Sample | Per cent Infested | |
| Elberta | 197 | 4.5 | 210 | 10.5 | + 6.0±2.6 |
| Roberta | 200 | 63.0 | 200 | 41.0 | —22.0±5.0 |
| Fox Seedling | 200 | 22.0 | 190 | 14.7 | — 7.3±3.9 |
| Iron Mountain | 195 | 73.8 | 200 | 60.0 | —13.8±4.7 |
| Krummel I | 204 | 83.3 | 202 | 75.7 | — 7.6±4.0 |
| Krummel II | 195 | 24.1 | 204 | 28.4 | + 4.3±4.4 |
| Total | 1,191 | | 1,206 | | |
| Per cent of total infestation | | 45.3 | | 38.5 | — 6.8±2.0 |

When the standard error due to fluctuations of sampling is computed by a method applicable to association tables (*1*, p. 381) it appears that the unexpected difference of + 4.3 per cent in one experiment is less than the standard error for this sample and therefore is not significant. The standard error of the difference of + 6.0 per cent recorded in the Elberta experiment is 2.6, which is too small to fully offset the unexpected positive value obtained. It is very likely that the reversal of trend noted in this case was not due to sampling but to broadly diffused fluctuations in density of infestation which can not be wholly eliminated as a source of error in any selection of plots, and can be reduced to insignificant proportions only by mutually compensating replicas of the experiment. A comparison of each of the other four differences noted, including the differences for total infestation, with its computed standard error indicates values that are significant. In four of the six experiments, then, the differences are statistically significant, with an expected trend in favor of the plots where liberations were made. The decreases range from 7.3 to 22.0 per cent. In the results in the block in which an increase of 4.3 per cent was noted, the contrary trend may have been due in part to inhibition of parasite activity through application of a lime-sulphur dust, known to repel Trichogramma, just before the time of liberation. Other orchards were not dusted during the experiments. The average infestation for the six blocks was 38.5 per cent for the liberation areas and 45.3 per cent for the checks, an advantage in favor of the liberation blocks of 6.8 per cent.

In 1931, the experiments were repeated on an enlarged scale, with some improvements in technique and methods. Liberations were

made in ten blocks including the same varieties. More care was used in selecting the blocks. In most cases all portions of both experiment and check were surrounded by trees of the variety tested. (See Figure 26.) In all cases two buffer rows intervened between the liberation block and its check, and the plots were so arranged that the liberation block was situated between two check plots. In all plots certain trees were selected for observations on the extent of parasitism by Trichogramma.

The numbers of parasites liberated per tree remained the same as last year, approximately 500 unemerged parasites being placed in the top of each tree. Each liberation included fresh, practically unretarded stock, in a mixture of at least three different ages, thus including parasites of different stages of development from those on the point of emerging to those just deposited in host eggs. The purpose of this was to obtain a prolonged span of emergence, which was considered desirable for highest effectiveness with this parasite. Each unit of liberation was enclosed in a small glass vial capped with 40-mesh wire, permitting the exit of parasites but preventing the invasion of ants and other predators.

Owing to the fact that this year the parasites were placed in the field nearer to the commencement of parasite emergence, the timing of liberation was changed to a point nearer to fruit-picking time. The following arrangement in a series from the greatest to the least reduction of infestation seems to indicate that from 21 to 24 days previous to picking approaches the optimum for the method used and that 18 to 19 days may have been too near to picking time.

| —14.1 | —6.2 | —4.8 | —4.6 | —3.7 | —3.3 | —2.1 | —1.7 | +0.9 | +1.3 |
|---|---|---|---|---|---|---|---|---|---|
| 23 | 24 | 24 | 21 | 24 | 19 | 18 | 19 | 28 | 18 |

A uniformly satisfactory emergence was obtained, equalling, in the plots in which estimates were made, 390 adults per tree, or about 42,900 per acre.

The amount of parasitism in the releasement blocks and the checks was determined by three observations made, respectively, just before releasement, 6 days after releasement, and 11 days after releasement. Small lozenges of leaf, bearing from one to three freshly deposited eggs, were attached to leaves on the selected trees and were allowed to remain until the blackened parasitized eggs were evident, when the results were recorded as positive or negative for each location. Approximately 20 locations were observed for the liberations and 20 others for the checks in each experiment. For some undetermined reason, the parasitism obtained from this method of checking was at all times very low, and almost certainly did not represent a true quantitative measurement of the parasitism by Trichogramma present in the orchards under test. In each of the three check-ups of parasitism, approximately 340

tests were made, which were about equally divided between liberation and checks. On the pre-releasement check-up, 2.8 per cent were positive for the liberation blocks and 2.7 per cent for the checks. On the sixth day check-up the positives in the liberation blocks had increased to

TABLE 2. THE PERCENTAGE OF INFESTATION OBTAINED IN FRUIT SAMPLES FROM EXPERIMENTAL PLOTS FOLLOWING LIBERATION OF *Trichogramma minutum* IN 1931

| Variety | Date of picking | Number of Days, liberation to picking | Check | | Liberation | | Per cent increase or decrease compared with check |
|---|---|---|---|---|---|---|---|
| | | | Number in sample | Per cent infested | Number in sample | Per cent infested | |
| Elberta I.... | Aug. 26 | 18 | 533 | 5.4 | 523 | 6.7 | + 1.3±1.5 |
| Elberta II... | Aug. 28 | 19 | 521 | 2.5 | 508 | 0.8 | — 1.7±0.8 |
| Roberta I... | Sept. 14 | 28 | 518 | 6.7 | 510 | 7.6 | + 0.9±1.6 |
| Roberta II.. | Sept. 10 | 24 | 510 | 9.2 | 500 | 3.0 | — 6.2±1.5 |
| Fox Seedling I..... | Sept. 14 | 24 | 409 | 12.9 | 417 | 8.1 | — 4.8±2.1 |
| Fox Seedling II..... | Sept. 10 | 19 | 512 | 6.6 | 444 | 3.3 | — 3.3±1.4 |
| Iron Mountain..... | Sept. 21 | 23 | 489 | 47.3 | 516 | 33.2 | —14.1±3.1 |
| Krummel I.. | Sept. 25 | 21 | 509 | 44.8 | 510 | 40.2 | — 4.6±3.0 |
| Krummel II. | Sept. 23 | 18 | 416 | 43.7 | 497 | 41.6 | — 2.1±3.2 |
| Krummel III | Sept. 28 | 24 | 281 | 60.1 | 280 | 56.4 | — 3.7±4.2 |
| Total..... | | | 4,698 | | 4,705 | | |
| Per cent of total infestation..... | | | | 21.8 | | 18.8 | — 3.0±0.8 |

7.2 per cent, while in the checks they had fallen to 0.6 per cent. On the eleventh day check-up, 1.7 per cent of the tests in the liberation blocks and 3.6 per cent in the checks were positive. These tests indicated low uniform parasitism in both liberation blocks and checks before liberation, followed by a definite increase in the liberation blocks after liberation, this increase disappearing by 11 days after liberation.

A sample of about 500 peaches was taken from each block, amounting for all the experiments to 9,403 peaches, or about 49 bushels of fruit. Old side-injury, fairly common this season, was not included in the counts. The fruit was cut for determination of the percentage of infestation. The results are included in Table 2.

It will be observed that the results obtained are similar to those secured in 1930. When the standard error of difference is computed, it appears that the two small positive differences which are contrary to trend are both less than their respective standard errors and therefore not statistically significant either as to amount or as to trend. For the same reason the small negative difference in the final two, namely, —2.1 and —3.7 are not statistically significant. The six other individual experiments have differences of the same expected trend. Al-

though these are small they all exceed their respective standard errors and therefore are statistically significant. The minus difference of 3.0, under per cent of total infestation, is small also, but is nearly four times its standard deviation and so is of relatively high reliability. Except for the 14.1 per cent reduction recorded in the Iron Mountain block, decreases were not economically significant, there being only 3.0 per cent reduction from the 21.8 per cent recorded as an average of the infestation in all the check blocks. A closer scrutiny of the table shows that all those varieties ripening before September 15, including Roberta and Fox Seedling as well as Elberta, were only moderately infested, a rather unusual condition in New Jersey. The Krummel and Iron mountain, ripening after September 20, were heavily infested. In this series of tests the reduction apparent in the liberation blocks in the first group, in relation to the portion remaining infested, is distinctly more favorable than in the more heavily infested second group. In this second group, where the highest degree of effectiveness from such a parasite liberation would naturally be expected, there was an average of 47.7 per cent infestation in the checks, and 41.1 per cent in the liberation blocks. This is a reduction of only 6.6 per cent, which is less than one-sixth the infestation still remaining.

Conclusion. Our interpretation of the results so far secured is that a slight reduction of fruit infestation usually follows the mass liberation of *Trichogramma minutum* in southern New Jersey, when released in such a manner as to insure the distribution of approximately 400 adults in each tree, at about 24 days previous to fruit picking. Under methods of production and handling now in use, it is estimated that the cost of obtaining and placing the parasites in the orchards in properly protected containers, one to each tree, would be not less than 18 cents per tree. It is quite evident that the average results obtained in our experiments would not justify the expense of rearing and liberating the parasites. It is quite possible that by changing the methods used, more favorable results would be obtained, or that the results with the same or different methods in other sections might prove more favorable. But it is also believed that our results do indicate the advisability of not embarking on large-scale control operations with this parasite until it has been shown by properly controlled experiments in the section concerned not only that mass liberations actually result in an increase of parasitism above the normal for this species in untreated orchards, but that such liberations are actually followed by noteworthy reductions of the fruit infestation.

## Literature Cited

1. Yule, G. U. An Introduction to the Theory of Statistics, 1927.

# PRELIMINARY EXPERIMENTS WITH NEW SPRAY MATERIALS AGAINST THE ORIENTAL FRUIT MOTH[1]

By S. W. Frost, *The Pennsylvania State College*

Abstract

Some figures are presented showing positive as well as negative results against the oriental fruit moth (*Laspeyresia molesta*) with one per cent oil emulsions and sodium aluminum fluoride.

The following experiments were conducted with the idea of finding some spray material that would be irritating or toxic to the larvae of the oriental fruit moth. Sodium aluminum fluoride and one per cent oil emulsions were used. Oils have not heretofore been used for this purpose, although they have been tried without success against the overwintering larvae.

Spray Tests on Fruit at the Laboratory. Individual fruits were sprayed from four angles with an atomizer. They were hung on racks by means of wires, and the spray allowed to dry before eggs were placed on them. In test No. 1, eggs ready to hatch were attached to the fruit, but in the remaining experiments, microscope slides were wired to the fruit to take the place of foliage, and the eggs were attached to the bottom of the slide. This change was made because oriental fruit moths never lay their eggs on the peach but upon the foliage, and the newly-hatched larvae must wander a considerable distance before reaching the fruit. After the fruits were arranged on the racks and eggs fastened to each slide, they were left for three weeks and then cut to determine the percentage of wormy fruit. At first paper cups or dishes containing water, were placed beneath each fruit to catch the young larvae which fell off, also to show traces of borings. These were later discontinued as wormy fruit gave the best index of failures to kill the larvae. It was determined by rearing, that all of the larvae which entered the fruit succeeded in maturing. Eggs were placed on the check fruit, with the one exception cited in footnote No. 4 in test number 6, and these fruits were handled the same as the sprayed fruit.

As these were the first experiments of this kind used against oriental fruit moth, the method had to be worked out as the work progressed. The per cent of wormy fruit in tests 1 and 2 was determined by recovering dead larvae in dishes and by observing entrance of larvae into fruits. As noted above, this method was not as satisfactory as cutting

[1]Publication authorized by the Director of the Pennsylvania Agricultural Experiment Station as technical paper No. 540.

fruit at the end of three weeks and noting the wormy fruits. Tests 3, 4, 5 & 6 were conducted in this manner.

The most remarkable results are shown in test No. 6 where one per cent oil (d) was applied to the slides only, the fruit and eggs receiving no spray, with the result that 97.2 per cent of the larvae were killed against 25 per cent in the check.

TABLE 1. SPRAY TESTS ON FRUIT AT THE LABORATORY

| Material | Number of fruit | Number larvae entering fruit | Per cent larvae entering fruit | Per cent dead larvae |
|---|---|---|---|---|
| **Test No. 1. June 30, 1931. Eggs attached to fruit** | | | | |
| Sod. Alum. Fluoride | 30 | 6 | 20.0 | 80.0 |
| A. Lead + 1 per cent oil (c) | 30 | 2 | 6.6 | 93.4 |
| Check | 30 | 27 | 90.0 | 10.0 |
| **Test No. 2. July 14, 1931. Eggs attached to glass slide** | | | | |
| Sod. Alum. Fluoride | 35 | 10 | 28.0 | 72.0 |
| A. Lead + 1 per cent oil (c) | 35 | 1 | 2.8 | 97.2 |
| A. Lead | 35 | 5 | 14.0 | 86.0 |
| Check | 25 | 34 | 97.1 | 2.9 |
| a, b, c—different commercial brands of spray oils. | | | | |
| **Test No. 3. July 27, 1931. Eggs attached to glass slides** | | | | |
| Sod. Alum. Fluoride | 35 | 22 | 62.8 | 37.2 |
| A. lead + 1 per cent oil (c) | 35 | 0 | .0 | 100.0 |
| A. Lead | 35 | 14 | 40.0 | 60.0 |
| Check | 35 | 32 | 91.4 | 8.6 |
| **Test No. 4. June 27, 1931. Eggs attached to slides[1]** | | | | |
| Sod. Alum. Fluoride | 60 | 28 | 41.6 | 53.4[2] |
| A. Lead + 1 per cent oil (c) | 60 | 29 | 48.3 | 51.7[2] |
| Check | 60 | 54 | 90.0 | 10.0 |
| **Test No. 5. Aug. 17, 1931. Eggs attached to slides** | | | | |
| One per cent oil | 95 | 0 | .0 | 100.0 |
| A. Lead + 1 per cent oil (c) | 95 | 1 | 1.0 | 99.0 |
| Lime | 35 | 30 | 88.6 | 11.4 |
| Check | 95 | 83 | 87.3 | 2.7 |
| **Test No. 6. Sept. 9, 1931. Eggs attached to slides** | | | | |
| 1 per cent oil (a) | 60 | 15 | 25.0 | 75.0[2] |
| 1 per cent oil (b) | 60 | 7 | 11.6 | 88.4[2] |
| 1 per cent oil (c) | 35 | 11 | 31.4 | 68.6[2] |
| 1 per cent oil (d) | 35 | 1 | 2.8 | 97.2[3] |
| Check | 60 | 45 | 75.0 | 25.0 |
| Check | 100 | 6 | 6.0 | —[4] |

[1]Test No. 4 was conducted on apples, all others on peaches.
[2]A light application of sprays to fruit and slides.
[3]A heavy application of oils to slides only.
[4]No eggs attached to fruit, 6 per cent represents the natural infestation.
a, b, c, d—different commercial brands of spray oils.

SPRAY TEST ON FOLIAGE OF PEACH. A number of commercial spray oils were sprayed on one year and five year old peach trees at the laboratory. These oils are indicated in Tables 1 and 2 by the letters a, b and c.

They are all summer oils recommended for apple, and in some cases for peach. Varying amounts of injury determined by the appearance of the foliage, resulted from the application of some of these oils. A few of the oils showed no apparent injury to fruit or foliage.

TABLE 2. SPRAY TESTS WITH OILS ON ONE YEAR PEACH TREES

| Date of application | No. of trees | Material[1] | Type of Injury July 30 | August 15 | September 8 | October 13 |
|---|---|---|---|---|---|---|
| June 26. | 1 | Oil (c) A. Lead+lime | slight | considerable | considerable | no defoliation |
| July 30. | 2 | Oil (c) | slight | considerable | considerable | no defoliation |
| Aug. 3.. | 1 | Oil (a) | — | none | none | no defoliation |
| Aug. 3.. | 1 | Oil (b) | — | none | none | no defoliation |
| Aug. 10. | 1 | Oil (c) | — | slight | considerable | no defoliation |
| Aug. 10. | 1 | Oil (c)+lime | — | slight | considerable | no defoliation |
| Aug. 15. | 1 | Oil (a) | — | —— | none | no defoliation |
| Aug. 15. | 1 | Oil (b) | — | —— | none | no defoliation |

[1]Oils were used at the rate of 1 gallon, arsenate of lead 3 pounds and lime 5 pounds to 100 gallons of water.
a, b, c—Commercial brands of summer spray oils.

TABLE 3. SPRAY TESTS WITH OILS ON FIVE YEAR PEACH TREES

| Date of application | No. of trees | Material | Type of Injury May 1 | June 30 | Aug. 15 | Sept. 8 |
|---|---|---|---|---|---|---|
| April 2[2]. | 1 | 3 per cent oil emulsion (d) | none | none | —— | —— |
| June 26. | 1 | 1 per cent oil emulsion (c) | — | none | —— | —— |
| July 1.. | 1 | 3 per cent oil emulsion (e) | — | severe | severe | partial defoliation |

[2]Peach in full bloom at this time.
(c) Commercial brand of summer spray oil.
(d and e) Cold mixed red engine oil emulsion.

The application on April 2, Table 3, was a cold-mixed emulsion. The stock solution was prepared March 11, 1930 and applied more than a year later. A red engine oil having a viscosity of 200 at 100°F., a specific gravity between 19.7 and 20.7 and 3 per cent unsaturated hydrocarbons, was emulsified with calcium caseinate, using three gallons of oil to one pound of calcium caseinate.

Incidentally the red engine oil mentioned above, as well as kerosene, was applied to apple foliage on July 14th with an atomizer. The heavy oil gave only slight burning where the leaves were drenched. Later in the season the tree showed scarcely any signs of injury. The light oil gave no burning.

SPRAY TESTS IN A COMMERCIAL PEACH ORCHARD. Sodium aluminum fluoride was applied to forty Krummel trees on June 26 and again on July 23. In both cases 3 pounds were used to 100 gallons of water

with the addition of no other materials. A one per cent summer oil emulsion was applied to forty Krummel trees with the addition of 3 pounds of arsenate of lead and 4 pounds of hydrated lime.

On August 10, slight burning was noticed where sodium aluminum flouride was applied and more serious injury where the one per cent oil emulsion, lead and lime was applied. Because of lack of previous knowledge with the use of summer oils on peach, we had unfortunately selected oil (c) most toxic to peach foliage and were forced to discontinue these experiments.

On October 1, the sodium aluminum fluoride plot showed a ragged appearance due to slight burning and some premature falling of leaves. At this time the one per cent oil plot showed rather severe burning to fruit and foliage and conspicuous premature falling of leaves.

A count was made at picking time and no apparent reduction of wormy fruit was noticed in the plot receiving sodium aluminum fluoride. The treated plot showed 20.1 per cent wormy fruit while the check showed 22.3 per cent wormy fruit.

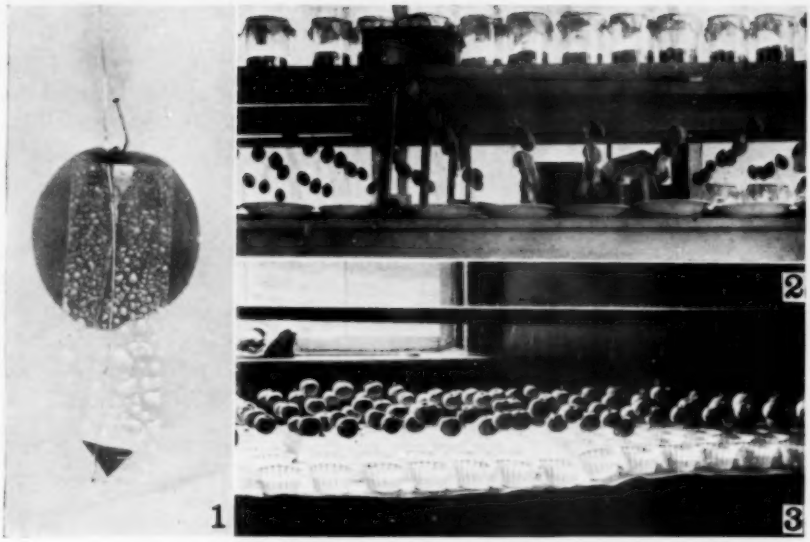
Nature of the Oil Injury on Peach. The oil injury first appeared on the foliage as small reddened areas, usually throughout the center portion of the leaf, not along the edges. Later these areas became dead, turned brown and fell out, leaving small holes in the leaf varying from one to two millimeters in diameter. It had a superficial resemblance to injury by shot-hole fungus.

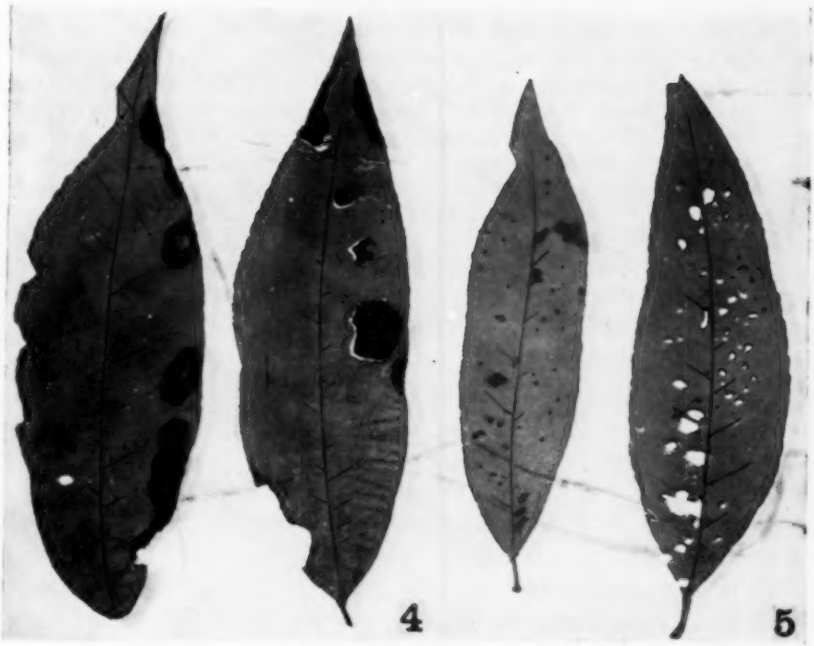
Discolored reddish blotches were produced on the fruit where heavy applications of three per cent oil emulsions were used during the summer. This discoloration was pronounced, and considerable gum oozed from the fruit. Some discoloration was also noticed when one per cent oil (c) was used.

Sodium aluminum fluoride produced burning along the edges of the leaves. At first the burned areas were slightly discolored. Later they turned brown and finally fell away from the leaf giving it a very ragged appearance.

Conclusions. The experiments show that a one per cent oil emulsion kills a high percentage of newly-hatched oriental fruit moth larvae. Just how the oil acts is unknown, but apparently it is disagreeable to the larvae for they fall off and never gain entrance to the fruit. That none of the eggs in these experiments were sprayed with oil would indicate that a better kill could be expected under orchard conditions when a percentage of the eggs would surely be hit by the spray.

Although much burning was experienced with summer oils at the dilution of .1 gallon to 100 of water, some of the oils produced no ap-




1, Method of hanging peach. Egg ready to hatch attached to slide; 2, Above rearing jars to obtain eggs. Below, peaches with eggs attached to slides; 3, A set of apples with eggs attached to fruit; 4, Burning on peach foliage produced by sodium aluminum fluoride; 5, Burning on peach foliage produced by oil emulsion (a).

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parent injury, and there seems to be a possibility of finding an oil that can be used with safety on peaches during the growing season.

Oils may present other limitations in their use because of the difficulty of removing the residue at picking time and because of discoloration of the fruit.

Sodium aluminum fluoride at the rate of 3 pounds to 100 gallons of water caused considerable burning and did not give a high percentage of control.

## EFFECT OF ARTIFICIAL ILLUMINATION ON THE ORIENTAL FRUIT MOTH UNDER ORCHARD CONDITIONS[1]

By BYRLEY F. DRIGGERS, *Associate Entomologist* and B. B. PEPPER, *Assistant New Jersey Agricultural Experiment Station*

ABSTRACT

A study of the effect of light from ordinary electric light bulbs on egg deposition by the Oriental Fruit Moth was made on several varieties of peaches at New Brunswick and Moorestown, N. J. The lights were suspended above the trees in such a way that groups of trees received different degrees of illumination ranging from 0 to 10 or more foot candles. One tree in each of three tests was illuminated from above and below so that all parts of the tree received illumination of an intensity of 10 foot candles or more. The lights were burned nightly or at such times as the moths showed activity. A photo-electric relay and thermostat was used to switch the lights on and off at the desired light intensity and temperature in the orchard. The effect of the lights on egg deposition was measured by counting the number of injured twigs caused by first and second brood larvae and by the percentage of injured fruit at harvest. No repellancy of the moths was noted in any of the tests. No pronounced attraction of the moths by the light was evident either.

It is a common observation that the Oriental Fruit Moth and Codling Moth show little activity during the bright part of the day but become quite active about sundown and after, when the light intensity drops to a comparatively low point. The observations of Peterson and Haeussler (3, 4) and Stearns (5) on the effect of ordinary yellowish-white electric lights of less than 100-watt capacity on fruit moths in the orchard, while they did not show any definite repellancy, failed to show any noticeable attraction. Peterson and Haeussler (4), working with small cages under laboratory conditions, found that Codling Moths and Oriental Fruit Moths reacted somewhat similarly to light and that the blue and violet end of the spectrum was more attractive than the red and yellow end. Herms (1), using six 500-watt Mazda lights suspended over a block of 15

[1]Paper of the Journal Series, New Jersey Agricultural Experiment Station, Department of Entomology.

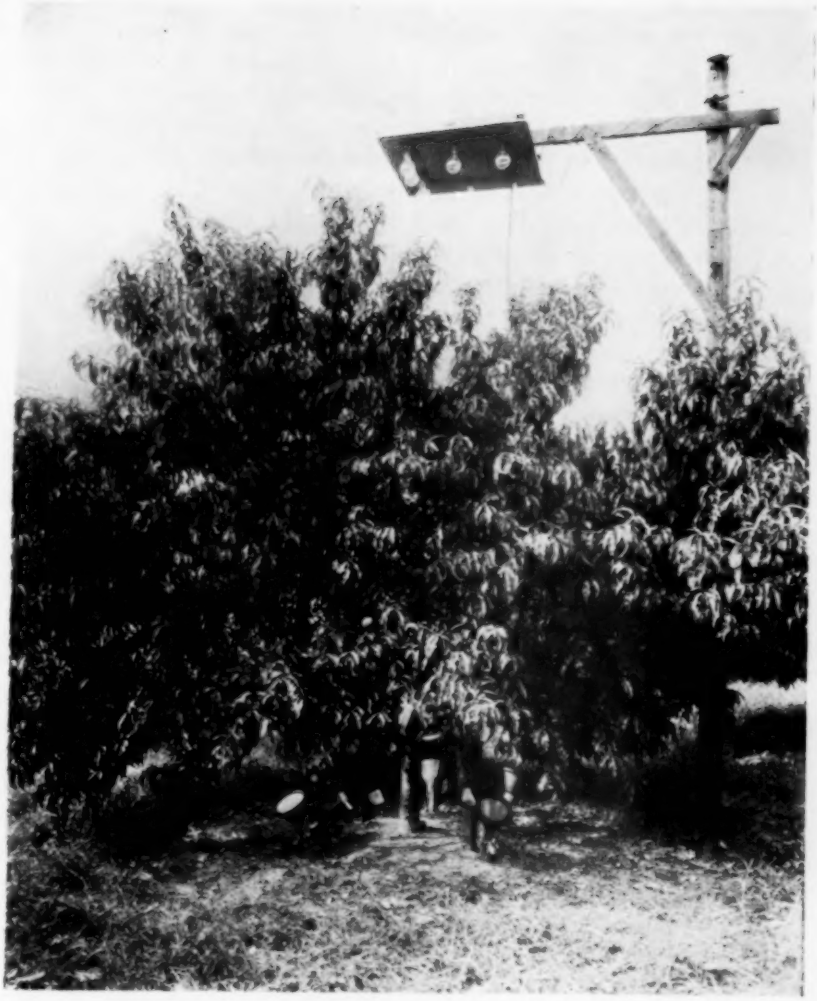
apple trees, reported a definite reduction in the egg laying activity of Codling Moths as shown by counts of apples injured by first brood worms. The battery of lights, which were illuminated for from two and a half to three hours each evening beginning about one-half hour before sunset, maintained a light intensity of approximately 4 foot candles under the lights. Herms found the highest percentage of moth attacked apples in that part of the orchard where the light intensity by artificial illumination remained for the evening at from 0.3 to 0.4 foot candles which he says was the intensity of natural light shortly after sunset.

Isley and Ackerman(2) and others have observed that Codling Moth egg deposition is greatly affected by the orchard temperature. Egg deposition by this species is greatly reduced when the temperature falls to 62° F or below. It is believed that the Oriental Fruit Moth is affected similarly by low orchard temperatures. The writers have observed that fruit moths in cages under insectary conditions deposit few eggs when the temperature during early evening falls to 65°F or below.

The observations and experiments cited in the preceding paragraphs, and particularly that of Herms in respect to the Codling Moth, was of such a nature that it appeared worth while to conduct orchard experiments to determine the effect of artificial light on egg deposition by the Oriental Fruit Moth. This paper sets forth data on twig and fruit injury from experiments conducted at New Brunswick and Moorestown in which peach trees of several varieties were subjected to different degrees of illumination during the time moths were active in the orchard.

Methods and Equipment. Three groups of lights were set up in peach orchards for the experiments on Oriental Fruit Moths. One set was installed in a six-year old block of mixed varieties in the college farm orchard at New Brunswick. The two remaining sets were installed at Moorestown, one in a large block of Elbertas and the other in a large block of Krummels. Both the Krummel and Elberta blocks were made up of six-year-old trees, the former planted only with peaches while the latter was interplanted with apples which were still too young to bear fruit.

The set up of the experiment at New Brunswick (followed in its essentials in the set up of the experiments at Moorestown) was as follows. The fourth tree in from the edge of the block on an Elberta row was selected and a pole erected 6 feet from the base of the tree. A cross arm was attached to the pole extending over, and about five feet above, the top of the tree. A tin reflector 4′ X 4′ carrying ten ordinary light sockets was attached to the cross arm. Four 200-Watt Mazda lights were inserted in the reflector at first, the number being



Arrangements of Lights in Orchard at New Brunswick

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increased to eight later to secure the desired illumination. The experiment was run from April 25 until the fruit was harvested in September. The lights were switched on at or a little before sundown and were allowed to run all night unless the temperature dropped to 60°F or below at which point the lights were switched off. For the first two weeks the lights were switched on and off by hand until automatic equipment could be installed.

The writers used a portable General Electric foot candle meter capable of measuring from 0.002 to 100 foot candles to measure the light intensity. A number of readings were made with the foot candle meter in the orchard to determine the natural light intensity at sunset and to determine when moths became active. The natural light intensity at sunset in the orchard averaged 4 F. C. A number of observations in the orchard showed the moth activity began around ten foot candles, therefore the automatic equipment was adjusted to switch the lights on when the natural light intensity decreased to 12 foot candles.

Automatic equipment was used to switch on the lights when the natural light decreased to the critical point and to cut them off when the natural light increased beyond the critical point and also to switch them on and off as the temperature rose above or below 60° F. To accomplish these results a sensitive photo-electric relay, a magnetic contactor and a thermostat were used. The photo-electric relay, which was capable of adjustment to operate at different light intensities, was wired in such a way as to operate the magnetic contactor to close and open the light circuit. The thermostat, adjusted to operate at 60°F. was inserted between the photo-electric relay and the magnetic contactor. One set of automatic equipment as described above was used to operate the two groups of lights at Moorestown and one set to operate the group of lights at New Brunswick.

Shortly after the overhead lights were installed it was noted that the top and center of the tree was well lighted but the underside of the leaves, particularly in the lower half of the tree, received very little illumination. To remedy this situation the writers had constructed and installed five ground reflectors each carrying a 100 watt bulb. These were arranged in such a way as to provide illumination from below of approximately ten foot candles. Plate 16 shows the complete outfit as operated throughout the summer. The outfit at New Brunswick was out of commission one night during the season due to damage by an electrical storm. The outfit at Moorestown operated almost equally as well, being out of commission three nights during the season due to the development of short circuits.

The arrangement of the experiment was such as to allow for one tree in each of the three tests which was illuminated from above and below to the extent of ten foot candles or more. The top of the tree received a much higher illumination than 10 foot candles because the reading of the foot candle meter when held chest high when the operator was standing at the center of the tree averaged between 30 and 50 foot candles. The trees in any direction from the well lighted tree received progressively less illumination, the amount of illumination received depending upon the distance of the tree from the light. The trees surrounding the lighted tree could be arranged in groups according to their distance from the lighted tree and according to the amount of illumination received.

To determine whether the lights had any effect on the oviposition of the Oriental Fruit Moth and if so at what light intensity, the writers determined (1) the number of twigs injured by first brood larvae, (2) the number of twigs injured by second brood larvae and (3) the percentage of fruit injury at harvest time. Each of the three sets of data would indicate the reaction of the moths to the lights. The three sets of data obtained from several varieties of peaches would tend also to smooth out differences in fruit and twig infestation which occur naturally in an orchard. The trees of any one variety were as nearly equal as regards twig growth and set of fruit as it was possible to obtain them.

The number of twigs injured by first and second brood and the percentage of fruit injured at harvest time on trees receiving different degrees of illumination at New Brunswick are set forth in Table 1. The data in this table show little or no correlation between the amount of illumination and the amount of injury. In respect to twig injury there was slightly more damage on the trees receiving the most illumination whereas the fruit injury was greater on the trees receiving the least or no illumination. The data in Table 1 show that the artificial illumination did not deter egg deposition even on the tree that was lighted to the extent of 10 F. C. or more.

Experiments at Moorestown, New Jersey. The experiments at Moorestown consisted of two light setups with overhead and under lighting similar to the one at New Brunswick. One was located in a solid block of Krummels and the other across a narrow road in a block of Elbertas interplanted with young non-bearing apple trees. The two sets of lights were, therefore, from the practical standpoint, in the center of a large block of peaches. The lights at Moorestown were burned the same as those at New Brunswick using clear Mazda bulbs and maintaining the illumination nightly until the last week of July. At that

time the determination of first and second brood twig injury had been made and it was evident that the light from the ordinary Mazda bulbs was not preventing the moths from ovipositing on the lighted trees.

TABLE 1. NUMBER OF TWIGS AND PERCENTAGE OF RIPE FRUIT INJURED BY ORIENTAL FRUIT MOTH LARVAE ON TREES ILLUMINATED AT DIFFERENT INTENSITIES AT NEW BRUNSWICK

| Tree Number | Light Intensity in F. C. | Number Twigs Injured | | | | Per cent Fruit Injured |
|---|---|---|---|---|---|---|
| | | First Brood | Second Brood | Both Broods | Av. each Intensity | |
| 1 | 10+ | 19 | 208 | 227 | 227 | 15.5* |
| 2 | 4–6 | 49 | 157 | 206 | | 22.6* |
| 3 | 4–6 | 25 | 212 | 237 | | 37.6† |
| 4 | 4–6 | 24 | 137 | 161 | | 16.5* |
| 5 | 4–6 | 44 | 190 | 234 | 209.5 | 35.6‡ |
| 6 | 1–3 | 14 | 168 | 182 | | 22.0† |
| 7 | 1–3 | 35 | 127 | 162 | | 33.7† |
| 8 | 1–3 | 35 | 187 | 222 | | 26.6‡ |
| 9 | 1–3 | 13 | 163 | 176 | 185.5 | 20.0‡ |
| 10 | .3–.6 | 36 | 200 | 236 | | 30.6‡ |
| 11 | .3–.6 | 24 | 126 | 150 | | 27.4* |
| 12 | .3–.6 | 12 | 153 | 165 | | |
| 13 | .3–.6 | 10 | 135 | 145 | | |
| 14 | .3–.6 | 21 | 189 | 210 | | 55.8† |
| 15 | .3–.6 | 11 | 207 | 218 | | |
| 16 | .3–.6 | 37 | 138 | 175 | | 29.1* |
| 17 | .3–.6 | 39 | 77 | 116 | | |
| 18 | .3–.6 | 23 | 123 | 149 | | |
| 19 | .3–.6 | 18 | 99 | 117 | 167.5 | |
| 20 | 0 | 14 | 138 | 152 | | |
| 21 | 0 | 30 | 289 | 319 | | |
| 22 | 0 | 35 | 296 | 331 | | |
| 23 | 0 | 18 | 214 | 232 | | |
| 24 | 0 | 13 | 200 | 213 | | |
| 25 | 0 | 22 | 286 | 308 | | 53.9† |
| 26 | 0 | 18 | 192 | 210 | | |
| 27 | 0 | 24 | 215 | 239 | | 34.2* |
| 28 | 0 | 15 | 86 | 101 | | |
| 29 | 0 | 4 | 75 | 79 | | |
| 30 | 0 | 12 | 198 | 210 | | |
| 31 | 0 | 7 | 100 | 107 | | |
| 32 | 0 | 12 | 156 | 168 | | |
| 33 | 0 | 8 | 157 | 165 | | |
| 34 | 0 | 18 | 179 | 197 | | |
| 35 | 0 | 31 | 115 | 146 | | |
| 36 | 0 | 22 | 190 | 212 | | 34.7* |
| 37 | 0 | 30 | 166 | 196 | 199 | 30.5* |

*Elberta variety, heavy crop.
†Hale variety, light crop.
‡Primrose variety, medium crop.

It was decided, therefore, to change the experiment and use red lights in the Elberta block and blue lights in the Krummel block for the remainder of the season.

The first and second brood twig injury and the percentage of visibly injured fruit at harvest time was determined in the Elberta block.

These data are set forth in Table 2. The data on visible injury are included in Table 2 because it appeared that most of this injury was caused by first and second brood larvae transferring from twigs to fruit and was, therefore, caused by larvae hatching from eggs deposited by

TABLE 2. NUMBER OF TWIGS AND PERCENTAGE OF FRUIT INJURED BY ORIENTAL FRUIT MOTH LARVAE ON ELBERTA TREES ILLUMINATED AT DIFFERENT INTENSITIES AT MOORESTOWN

| Tree Number | Light Intensity in F. C. | Number Twigs Injured | | | | Per cent Fruit Injured* |
|---|---|---|---|---|---|---|
| | | First Brood | Second Brood | Both Broods | Av. each Intensity | |
| 1 | 10+ | 44 | 74 | 118 | 118 | 4.1 |
| 2 | 4–6 | 34 | 85 | 119 | | 5.7 |
| 3 | 4–6 | 25 | 86 | 111 | | 4.7 |
| 4 | 4–6 | 20 | 70 | 90 | 106.7 | 3.8 |
| 5 | 0.5–2 | 19 | 56 | 75 | | 1.9 |
| 6 | 0.5–2 | 6 | 44 | 50 | | 5.8 |
| 7 | 0.5–2 | 20 | 85 | 105 | | 9.1 |
| 8 | 0.5–2 | 5 | 20 | 25 | | 1.9 |
| 9 | 0.5–2 | 34 | 72 | 107 | | 4.2 |
| 10 | 0.5–2 | 18 | 59 | 77 | | 13.6 |
| 11 | 0.5–2 | 34 | 109 | 143 | | 3.8 |
| 12 | 0.5–2 | 30 | 61 | 91 | | 3.8 |
| 13 | 0.5–2 | 37 | 71 | 108 | | 3.4 |
| 14 | 0.5–2 | 18 | 80 | 98 | | 3.7 |
| 15 | 0.5–2 | 4 | 70 | 74 | 86.6 | 9.6 |
| 16 | 0 | 15 | 68 | 83 | | 5.0 |
| 17 | 0 | 14 | 95 | 109 | | 2.4 |
| 18 | 0 | 21 | 64 | 85 | | 4.7 |
| 19 | 0 | 48 | 118 | 166 | | — |
| 20 | 0 | 19 | 90 | 109 | | — |
| 21 | 0 | 30 | 108 | 138 | | — |
| 22 | 0 | 9 | 80 | 89 | | 4.7 |
| 23 | 0 | 24 | 96 | 120 | | 5.9 |
| 24 | 0 | 17 | 69 | 86 | | 5.7 |
| 25 | 0 | 23 | 113 | 136 | | 3.8 |
| 26 | 0 | 8 | 64 | 72 | 108.4 | — |
| 27 | 0 | — | — | — | — | 3.4 |
| 28 | 0 | — | — | — | — | 5.6 |
| 29 | 0 | — | — | — | — | 4.0 |

*Visible injury only.

moths at the time the ordinary white lights were operating. Only the visible injury is given because the invisible injury at harvest time is practically all caused by larvae entering the fruit from the stem and during the week or two weeks previous to the time the fruit is harvested. Since the white lights were replaced by red lights in the Elberta block the last week in July and the fruit was not harvested until the last week in August, it is reasonable to assume that any invisible injury present was due to larvae hatching from eggs deposited after the red lights were installed.

The effect of the artificial light on egg deposition by the Oriental Fruit Moth on Elbertas at Moorestown as shown by the data in Table 2

was essentially the same as that shown at New Brunswick on mixed varieties. No diminution in egg laying as measured by twig and fruit injury was apparent even on the tree where the light intensity was kept at 10 F. C. or above. There was, if anything, slightly more twig injury

TABLE 3. NUMBER OF TWIGS INJURED BY ORIENTAL FRUIT MOTH LARVAE ON KRUMMEL TREES ILLUMINATED AT DIFFERENT INTENSITIES AT MOORESTOWN

| Tree Number | Light Intensity in F. C. | Number Twigs Injured First Brood | Second Brood | Both Broods | Av. each Intensity |
|---|---|---|---|---|---|
| 1 | 10+ | 73 | 79 | 152 | 152 |
| 2 | 7–9 | 26 | 43 | 69 | |
| 3 | 7–9 | 23 | 130 | 153 | |
| 4 | 7–9 | 19 | 45 | 64 | |
| 5 | 7–9 | 15 | 84 | 99 | 96 |
| 6 | 4–6 | 38 | 174 | 212 | |
| 7 | 4–6 | 25 | 99 | 124 | |
| 8 | 4–6 | 20 | 39 | 59 | |
| 9 | 4–6 | 7 | 30 | 37 | 108 |
| 10 | 0.5–2 | 14 | 5 | 19 | |
| 11 | 0.5–2 | 5 | 6 | 11 | |
| 12 | 0.5–2 | 12 | 154 | 166 | |
| 13 | 0.5–2 | 33 | 155 | 188 | |
| 14 | 0.5–2 | 15 | 204 | 219 | |
| 15 | 0.5–2 | 10 | 48 | 58 | |
| 16 | 0.5–2 | 12 | 34 | 46 | |
| 17 | 0.5–2 | 5 | 53 | 58 | |
| 18 | 0.5–2 | 53 | 47 | 100 | |
| 19 | 0.5–2 | 47 | 84 | 131 | |
| 20 | 0.5–2 | 5 | 14 | 19 | |
| 21 | 0.5–2 | 0 | 70 | 70 | 90.4 |
| 22 | 0 | 0 | 25 | 25 | |
| 23 | 0 | 47 | 127 | 174 | |
| 24 | 0 | 14 | 37 | 51 | |
| 25 | 0 | 16 | 85 | 101 | |
| 26 | 0 | 25 | 93 | 118 | |
| 27 | 0 | 29 | 77 | 106 | |
| 28 | 0 | 42 | 130 | 172 | |
| 29 | 0 | 13 | 15 | 28 | |
| 30 | 0 | 12 | 14 | 26 | |
| 31 | 0 | 4 | 25 | 29 | 83 |

on the well lighted tree than on the trees receiving less light or no light at all. There was little difference in fruit injury evident between the groups of trees. The differences in infestation noted from tree to tree, particularly in respect to twig injury, seemed to be due to differences in the growth status of the tree rather than to differences in the amount of light received. Those trees that showed the most succulent growth were the trees that had the most twig injury.

The data on twig infestation from the lighted Krummel trees are set forth in Table 3. The percentage of fruit infestation on these trees is omitted, the reason being that there was a heavy build up of infestation toward the latter part of the summer which tended to over-

shadow the small infestation of fruit caused by larvae of the first and second broods. Some idea of the extent of this late build up can be obtained when we compare the infestation on the Elbertas, which were picked the last week in August, to the infestation on Krummels, which were picked the last week in September. The Elbertas ran between five and ten per cent total infestation and the Krummels around fifty per cent total infestation. It would appear, therefore, that the bulk of the Krummel infestation occurred after the ordinary lights were replaced by blue lights the last week in July.

The data in Table 3, giving the extent of twig injury on lighted and unlighted Krummel trees, show the same trend in respect to the effect of lights on egg deposition by the fruit moth as was shown in the two previous tests. The moths oviposited as freely, if not more freely, on the well lighted as on the unlighted trees judging from the extent of the twig injury. The data in Table 3 show that there was fifty per cent or more injured twigs on the one well lighted tree as was found on an average for the trees receiving less light. These figures do not necessarily indicate that the moths were attracted to the well lighted tree to the extent the figures would indicate. There is a wide variation in the number of injured twigs from tree to tree therefore, it would be necessary to light a number of trees similar to the way in which tree number 1 of Table 3 was lighted before we could conclude that the figures represent moth attraction.

## References

1. Herms, W. B. 1929. A Field Test of the Effect of Artificial Light on the Behavior of the Codling Moth. J. Ec. Ent. 22: 78.
2. Isley, D., and Ackerman, A. J. 1923. Life History of the Codling Moth in Arkansas. Univ. Ark. Ag. Exp. Sta. Bull. 189.
3. Peterson, A., and Haeussler, G. J. 1926. The Oriental Peach Moth. U. S. D. A., Dept. Cir. 395.
4. Peterson, A., and Haeussler, G. J. 1928. Response of the Oriental Peach Moth and Codling Moth to Colored Lights. Ann. Ent. Soc. Am. 21: 353.
5. Stearns, L. A. 1926. Observations on the Effectiveness of Electric Lights in Attracting the Adults of the Oriental Peach Moth. Report Dept. Ent. N. J. Agr. Expt. Sta., p. 394.

# THE PRESENT STATUS AND FUTURE REQUIREMENTS OF THE GIPSY MOTH PROBLEM

By A. F. BURGESS, *Plant Quarantine and Control Administration, Greenfield, Mass.*

Active work to prevent the spread of the gipsy moth has been continued throughout the year. The results in New Jersey have been most encouraging. Cooperation with the State Department of Agriculture has been continued as heretofore. No treatment has been required as the insect has not been found in that State since the spring of 1929. The work has consisted of scouting in the central area and in selected localities where the chances for overlooking infestation appeared to be the greatest. This has been done as a matter of insurance in order that no steps might be neglected in making the extermination of this insect in New Jersey absolute.

In addition to this work, 887 assembling cages were placed in the field in localities in 29 townships which seemed to be the most suspicious but no moths were caught in these cages. Many of these cages were refilled during the season so that their efficiency was doubled.

When it is remembered that ten years ago more than 3,000,000 egg clusters of this insect were treated and over 400 square miles were infested, the results are very striking. Further scouting and checking up work will be carried on this winter and if no infestation is found the quarantine in the two remaining towns will be removed. General scouting and the use of assembling cages will be continued for a few years as a precautionary measure at a greatly reduced expense.

On account of the progress made in cleaning up the gipsy moth infestation near North Roslyn, Long Island, it was possible to reduce the area covered by State quarantine from a three mile to a two mile zone surrounding the center of original infestation. The scouting and clean-up work is being handled by the Conservation Department of the State of New York. The quarantine was promulgated by the Department of Farms and Markets of that State and all stock shipped from the area is being inspected and certified by the inspectors of the U. S. Plant Quarantine and Control Administration. During the fall scouting work which has been carried on since the egg clusters were deposited, four small infested areas have been found which will require further treatment and it is probable that very intensive work will have to be done in some of the woodland areas before this infestation is finally exterminated. These findings emphasize the fact that re-scouting and thorough check up work

extending over several years is absolutely necessary to bring about the extermination of this pest.

On account of the infestations in New Jersey and New York occurring in isolated areas State quarantines were declared which were enforced cooperatively by the States concerned and the Plant Quarantine and Control Administration.

The quarantine and inspection work in the New England States has been carried on by the Administration and has been very effective in preventing the spread of the insect to widely scattered points throughout the United States where products that might carry infestation are constantly being shipped.

The effort that is being made to protect all of the States west of New England from gipsy moth infestation has been continued and intensive work has been done in what is known as the barrier zone, in cooperation with the Conservation Department of the State of New York. Effective work has been done in exterminating colonies of the insect which from time to time have been found in the zone. As the work progressed it became apparent that more work was necessary in woodland areas before an exact knowledge of conditions in the zone would be available. Accordingly intensive woodland scouting was taken up in some of the Massachusetts, Connecticut and Vermont woodland areas of the zone that had not been examined heretofore and numerous infestations were found during the winter of 1930–31, in towns in southwestern Massachusetts, northwestern Connecticut and an extension of this area in New York State. Clean-up work was carried on in these infestations and spraying was applied in the spring of 1931. The location of some of these colonies in deep woodland was such that the spraying was the most difficult that had ever been attempted by this project and it is doubtful whether spraying has ever been carried on under more exacting conditions. Hose lines over 6,000 feet in length were frequently used and the semi-mountainous nature of the country added to the complications that had to be met.

The danger of infestation, particularly along the eastern borders of the zone, result principally from re-infestation coming in from territory directly east of the zone where considerable infestation must exist. The results of the scouting work in the fall of 1930 and the spring of 1931 tended to confirm this idea and during the past summer special effort was made to check up the conditions in localities where infestation had been found at any time since the zone was established, by putting up assembling cages to attract male moths during the summer. The cages were put up as indicated in the following table and a small number of

cages were placed in a few towns directly east of the zone where it seemed most likely that infestation might be present.

STATES WHERE CAGES WERE PUT OUT

| State | In Barrier Zone | | | East of Barrier Zone | | |
|---|---|---|---|---|---|---|
| | No. Cages Put Out | No. of Cages which Caught Moths | No. of Male Moths Caught | No. Cages Put Out | No. of Cages which Caught Moths | No. of Male Moths Caught |
| Vermont | 620 | 0 | 0 | 0 | 0 | 0 |
| Massachusetts | 958 | 29 | 56 | 300 | 18 | 30 |
| Connecticut | 777 | 21 | 36 | 407 | 4 | 9 |
| New York | 309 | 2 | 2 | | | |
| New Jersey | — | — | — | 887 | 0 | 0 |
| Totals | 2,664 | 52 | 94 | 1,594 | 22 | 39 |

A table listing the towns where male moths were taken follows:

TOWNS WHERE MALE MOTHS WERE FOUND

| State | In Barrier Zone | | East of Barrier Zone | |
|---|---|---|---|---|
| | Town | No. Male Moths Caught | Town | No. Male Moths Caught |
| Massachusetts | Becket | 2 | Blanford | 3 |
| | Lee | 3 | Chester | 2 |
| | Monterey | 1 | Granville | 20 |
| | New Marlboro | 22 | Tolland | 5 |
| | Sandisfield | 6 | | |
| | Sheffield | 18 | | |
| | Tyringham | 4 | | |
| Connecticut | Canaan | 3 | Barkhamsted | 1 |
| | Cornwall | 3 | Hartland | 6 |
| | Kent | 1 | West Hartford | 2 |
| | Litchfield | 2 | | |
| | Warren | 27 | | |
| New York | Milan | 1 | | |
| | Northeast | 1 | | |
| Totals | | 94 | | 39 |

Active scouting work is being carried on in woodland on the western border of the barrier zone north and south of Ticonderoga, New York, and the plan for the year calls for a continuation of this scouting in adjoining territory in the zone in Vermont together with smaller areas south of Rutland and in Conneticut, west of New Haven. Intensive scouting will also be carried on and clean-up measures applied wherever infestation is found in the towns that were infested last year and particular attention will be given to locating the source from which male moths were attracted to the cages that were used in the field this summer.

It is apparent that while excellent results have been secured in the barrier zone area, very thorough and intensive work will be required in order to permanently limit the spread of the insect and to maintain the advantage that has been secured by the previous work conducted in this zone.

## THE DISTRIBUTION OF THE JAPANESE BEETLE IN 1930 AND 1931, WITH SPECIAL REFERENCE TO THE AREA OF CONTINUOUS INFESTATION[1]

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ABSTRACT

The apparent total range of the Japanese beetle (*Popillia japonica*) is divisible into an area of continuous and one of discontinuous distribution. The former is alone considered. Maps are given showing the area of continuous distribution in 1930 and in 1931, and indicating the varying degrees of infestation within its limits. The size of the area is given, and it is pointed out that its expansion has not progressed uniformly in all directions. Heavy infestation is typical of open country and is of only local occurrence, or relatively light, in thinly settled and heavily wooded country, as the Pine Barrens of New Jersey. Areas of unusually intense, or maximum, infestation no longer coincide with the original center of the range, but each year shift their position farther out into later infested sections. The limits of the general area of continuous infestation and those of the various degrees of infestation considered are approximately defined by citation of localities.

In an earlier paper[2] the writer emphasized the fact that the apparent total range of the Japanese beetle (*Popillia japonica* Newm.) comprises two major subdivisions, in one of which the insect occurs at essentially all points where favorable environmental conditions obtain, while in the other it is known only in the form of more or less widely isolated local colonies. The former, to which in the paper in question was applied the term "normal range," evidently corresponds to the area which the insect has occupied mostly as a direct result of its natural spread year after year from the original center near Riverton, N. J. The latter, on the other hand, has been occupied only as a result of the artificial conveyance of the insect to new localities and its consequent establishment in the form of local colonies.

[1]Contribution No. 95, Japanese Beetle Laboratory, U. S. Bureau of Entomology, Moorestown, New Jersey.

[2]Fox, Henry. 1927. The present range of the Japanese beetle, *Popillia japonica* Newm., in America and some factors influencing its spread. Jour. Econ. Ent. 20: 383–391.

Within the past several years it has been a function of the Plant Quarantine and Control Administration to gather information on Japanese beetle occurrences in the area of discontinuous distribution. For this reason the writer has largely confined himself to the study of conditions as found in the area of continuous distribution. Accordingly, the present paper will be largely limited to a consideration of these conditions, with only incidental reference to those found in the much more extensive area of discontinuous distribution.

THE AREA OF CONTINUOUS DISTRIBUTION IN GENERAL. The areas of continuous distribution of 1930 and 1931 are shown in Figures 26 and 27 as the generally stippled portions of the maps, the heavier dots outside of the stippled areas corresponding to local occurrences in the adjoining part of the area of discontinuous distribution.[3]

In 1930 the northern periphery of the area of continuous distribution coincided with a line extending from Frenchtown, Hunterdon County, N. J.,[4] eastward through Flemington, and New Brunswick, to the ocean near Asbury Park. In 1931 the same periphery advanced north a distance of from 4 to 7 miles, to a position indicated by such places as Milford and Clinton, Hunterdon County; Somerville, Somerset County; Metuchen and Perth Amboy, Middlesex County; and Navesink, Monmouth County. Eastward all further spread in both years was barred by the ocean. Southward Delaware Bay was reached in 1930, resulting in no further spread in that direction, except in Cape May County, where in 1931 the periphery advanced a few miles south in the peninsular portion of the county. Westward, in 1930, the periphery of the area of

[3]The number of dots actually shown in the maps is doubtless much less than actual number of infestations, with the probable exception of those in New Jersey. It has been the policy of the Plant Quarantine and Control Administration to conduct no systematic survey of that portion of the area of discontinuous distribution which falls within the region designated by it as the generally infested area, and this includes practically all of the region shown in these maps. In New Jersey, however, the scouting done under the direction of G. K. Handle, in field charge of the Japanese Beetle Quarantine in New Jersey for the Plant Quarantine and Control Administration, has covered quite thoroughly nearly all of the discontinuous area of the State. It therefore seems probable that the maps herewith published present a fairly accurate picture of the state of Japanese beetle infestation throughout New Jersey, but the same can not be safely asserted as regards the number of local occurrences shown in the remaining States.

[4]The writer (op. cit.) erroneously listed this locality as the northern terminus of the normal range in 1926. Subsequent field experience and a review of the scouting records of that year show that the occurrence at Frenchtown was at that time a local occurrence, and that the actual range did not extend much, if at all, north of Lambertville.

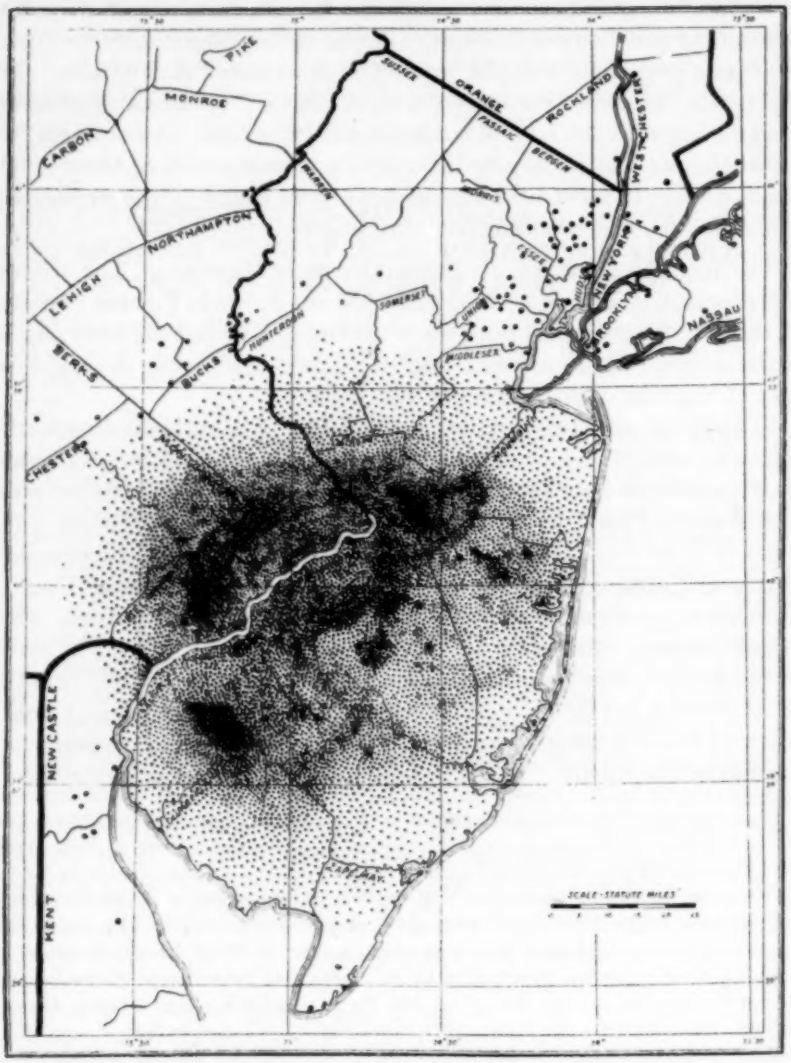


FIG. 26.—Map of New Jersey and parts of adjoining States showing the state of Japanese beetle infestation in 1930. The stippled portion shows the area of continuous distribution, the density of the dots within this area being indicative of the degree of infestation. The large black dots in the blank portion of the map show the known local occurrences of the insect in the part of the area of discontinuous distribution included within the map limits.

continuous infestation was indicated by the location of such places, in Pennsylvania, as Perkasie, Bucks County; and Phoenixville and Down-

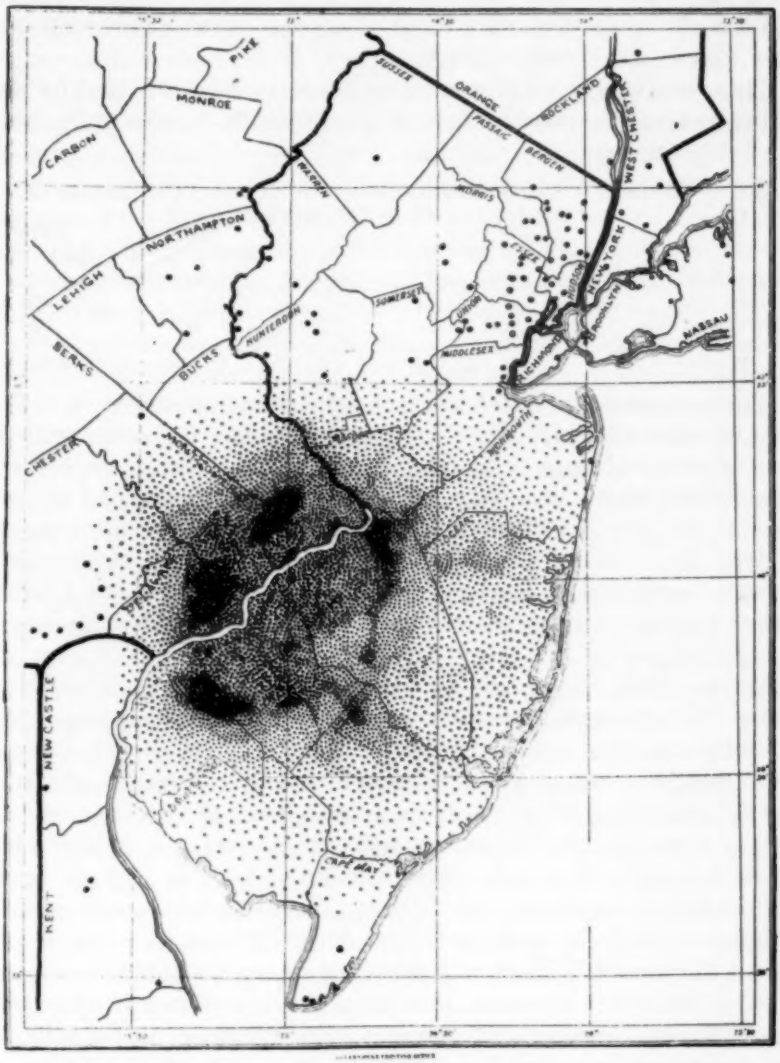


FIG. 27.—Map of New Jersey and parts of adjoining States showing the state of Japanese beetle infestation in 1931. Explanation as in Figure 26.

ingtown, Chester County; and, in Delaware, by Wilmington and New Castle. In 1931 it extended out to the general vicinity, in the for-

mer State, of Quakertown, Bucks County; Pottstown, Montgomery County; and Coatesville and Kennett Square, Chester County; while in Delaware it reached the western suburbs of Wilmington and terminated southwards on the Delaware River at a point about midway between New Castle and Delaware City.

The extent of the area of continuous distribution as estimated for each of the two years is shown in Table 1, together with the area in the different States involved.

TABLE 1. ESTIMATED SIZE OF THE AREA OF CONTINUOUS DISTRIBUTION OF THE JAPANESE BEETLE IN 1930 AND 1931

| State | 1930 Square Miles | 1931 Square Miles |
|---|---|---|
| New Jersey | 4,400 | 4,700 |
| Pennsylvania | 1,250 | 1.400 |
| Delaware | 50 | 100 |
| Total | 5,700 | 6.200 |

The increase in size of the total area of continuous infestation in 1931 thus amounted to only about 500 square miles. In comparison with the rate of spread of many other insect pests, as, for example, the Mexican bean beetle, which since 1920 has covered the entire distance between central Alabama and New England, this is extremely slow progress. Indeed, if it were not for the facilities afforded for rapid conveyance to distant points by commerce and travel, the spread of the Japanese beetle to other parts of this country would evidently be an unprecedentedly slow process.

Where serious barriers did not interfere, the advance of the periphery of the 1931 distribution area over that of the preceding year varied from 2 to 10 miles, the general average being about 5 miles. This accords fairly well with impressions formed in former years, when the Japanese beetle was limited in its continuous distribution to a more nearly uniformly favorable type of environment than was the case in later years, when influences of various kinds introduced local or regional irregularities into its rate of spread. Had the same apparent rate of spread of 5 miles a year held throughout, the linear distance from the original center to the entire periphery of the continuous range would now amount to 65 miles,[5] which is 5 miles in excess of the maximum reached in 1931. It is therefore obvious that obstacles have intervened in the course of the insect's advance to delay at time its general rate of spread.

[5]The dispersal from the original center near Riverton was not obvious before 1918. It first became clearly evident in 1919 and has progressed ever since. Consequently, at an average rate of 5 miles per year, the species would have travelled 65 miles during the 13 years intervening between 1918 and 1931

As was shown in the writer's former paper,[2] the most rapid expansion of the Japanese beetle's range was eastward toward the coast, which was first reached in 1926. The distance from the original center near Riverton to the nearest point on the coast is about 50 miles. This would give an average eastward advance during the eight years from 1918 to 1926 of about 6 miles per year. In the previous paper[2] the more rapid eastward expansion was attributed, in part at least, to the influence of the wind, which in the region under consideration is prevailingly from the west. It was also intimated that the eastward spread would probably have been even more rapid had not the relatively inhospitable region of the New Jersey Pine Barrens intervened. Since 1926, when the coast was reached, all further progress toward the east has been barred by the oceanic barrier.

Southward the expansion of the range proceeded at a general average rate of about 4.5 miles a year. In New Jersey, Delaware Bay was reached in 1930, which will probably seriously impede further spread in the same direction, except in Cape May County, where, however, advance has thus far been very slow, probably on account of the prevalence os sandy soils and of heavily wooded country, which offer few favorable breeding sites. The farthest point reached in this direction in 1931 was 60 miles from the original center of the range.

At the present time the chief unimpeded expansion of the Japanese beetle's range is to the north and west, although in the past the general rate of spread in these directions averaged below that toward the east and south. Toward the north, in the interval 1918–1931 the average rate of progress was about 3 miles a year, this increasing, however, toward the northeast to a rate of 4 miles. In 1931 the outermost point reached lay about 43 miles directly north of the original center, but by this time the expansion of the range northeast had carried its periphery in this direction as much as 55 miles beyond the same center. At the present time there are indications that the rate of advance northward, as well as westward, is increasing, a change doubtless conditioned by the general prevalence in the Piedmont sections of New Jersey and Pennsylvania of rich loamy soils and open farming country.

Toward the west the general rate of advance to date has been about 3 miles a year, but, as in the north, there is evidence that this rate is increasing. As has been intimated, this is probably connected with the general type of soil and country represented in eastern Pennsylvania, but it is also favored by the further fact that, within recent years, the most extensive areas of maximum infestation have come to occupy a position not far removed from the western limits of spread. (Figs. 26 and 27.) In

1931 the most western point reached was about 45 miles from the original center of the range.

Topographic features are of some influence as temporary barriers to spread. Thus, in 1931 the main lines of advance westward were witnessed in the valley of the Schuylkill River and through the long, troughlike Chester Valley, which extends diagonally across Chester County southwest into Lancaster County. In the belt of high, rugged country, known as the Welsh Mountains, lying between these two valleys, the advance in 1931 was apparently quite slight. Local topographic features of this kind account for some of the irregularities shown along the western border of the distribution area. (Figs. 26 and 27.)

It is of interest to contrast the distances to which, from 1918 to 1931, the Japanese beetle has been carried through its own efforts with those to which it has been conveyed through artificial agencies. The former range from 35 to 60 miles, whereas the distances in miles from the original center of the distribution area to certain of the more distant points at which Japanese beetle colonies are recorded are approximately as follows: Boston, Mass., 270; Buffalo, N. Y., 290; Columbus, Ohio, 430; Richmond, Va., 250; Norfolk, Va., 250; Charleston, S. C., 575.

DEGREES OF INFESTATION WITHIN THE AREA OF CONTINUOUS INFESTATION. In Figures 26 and 27 the density of the stippling within the general area of continuous distribution is roughly indicative of the degree of infestation found in its different parts. In general, the infestation is shown as markedly heavy in all of west-central New Jersey and southeastern Pennsylvania. In this entire region the wide prevalence of either open farming country or palatial suburban districts affords ideal conditions for the establishment and increase of the Japanese beetle. Similar conditions exist throughout practically all of northern New Jersey, Pennsylvania east of the Appalachians, and most of Delaware and Maryland. The same condition of general heavy infestation which now prevails in the vicinity of the Delaware River between Lambertville on the north and Penns Grove on the south may, therefore, be expected in most of the other adjoining parts of these States with the future spread of the insect. On the other hand, in the eastern half of south-central and southern New Jersey the infestation is indicated as relatively light, the exceptions being of a highly local character. Nearly all of this section of New Jersey is formed by the region known as the Pine Barrens, in which the almost universal presence of barren, sandy soils and the heavily forested condition of the country reduce to a minimum the lush grassy meadows and pastures which form the normal favorite breeding haunts of the beetle. The only exceptions to this rule are the infesta-

tions which have arisen in certain of the more extensively cleared areas, in which, as a result of settlement and cultivation, the original Pine Barrens have been radically altered and conditions have been produced not unlike those prevalent in the older settled, open country bordering the Delaware River.[6]

In 1930 the total area recognized as heavily infested was estimated at 2,200 square miles. In 1931 this increased to about 3,400 square miles.

In the heavily infested region the Japanese beetle is everywhere abundant enough to be a pest, though the damage done may vary considerably depending upon the age of the infestation. Near the periphery it is necessarily light, being transitional from moderately heavy to insignificant damage. In this transitional area tree damage is rarely obvious, but a variable amount of damage is usually apparent, marked by a more or less extensive riddling and discoloration of the foliage of grapes and other vines favored by the beetles for food. In the older infested area not only is vine damage more general and severe than in the transitional zone, but in addition obvious tree damage is of general occurrence, and in some instances, as the areas shown on the maps (Figs. 26 and 27) as solid, or nearly solid, black patches, is often quite severe.

Damage by the Japanese beetle is most conspicuously evident in the foliage of the trees and vines attacked. Feeding is confined to the softer tissues of the leaf, the veins being left intact. Leaves extensively skeletonized in this manner may soon wilt and turn a rusty-brown tint. Trees so discolored form conspicuous objects in the landscape, the autumn-like tint of their foliage contrasting strongly with the dark green of the surrounding vegetation. Not all forms of plant life are attacked with equal vigor and many are practically untouched. Some of the commonest trees of the region are never, or only rarely, damaged to an appreciable extent. Among these are nearly all the oaks, the maples, the gums (Nyssa, Liquidamber), the beech, tulip tree (Liriodendron), and the most abundant of the wild cherries, *Prunus serotina* Ehrh. as also, among vines, the ubiquitous poison-ivy, *Rhus radicans* L. On the other hand, all other forms of cherry, especially the cultivated varieties, are heavily attacked and often severely damaged, as are also such other trees as linden (Tilia), sassafras, horse-chestnut (Aesculus), elm, and, at times, buttonwood (Platanus). This is also true of such common vines, as grape, both wild and cultivated, Virginia creeper,

[6]The writer has commented elsewhere upon the changes induced by settlement and cultivation in the Pine Barrens. See Fox, Henry. A revised annotated list of the Dermaptera and Orthoptera of New Jersey. N. J. Dept. Agr. Circ. 138, 59 p.

*Parthenocissus quinquefolia* (L.), and some varieties of cultivated ivy. Among herbaceous types, the common smartweed, *Polygonum pennsylvanicum* L., is especially attractive, and often harbors many beetles when scarcely any can be found on other types of food plants.

In most of the generally heavily infested area it is only occasionally that full-grown trees occur with all, or the vastly greater part of, their foliage riddled and discolored from beetle attacks. It is only in local areas of maximum infestation, shown on the maps as solid, or nearly solid, black patches, that any considerable proportion of the trees show this condition. Typically, however, in the general area of heavy infestation at the present time, rather less than half of the foliage of such trees as are favored by the beetles shows obvious injury.[7]

It is rather difficult to give the precise eastern limits of the area of general heavy infestation, as its continuity in that direction is interrupted by the Pine Barrens, although it can now be traced in isolated cleared areas clear across that region as far as Toms River, Ocean County. If, disregarding its discontinuity in this region, such points as this are accepted as marking its outer limits, the bounds of the area of general heavy infestation, in 1930, were indicated, in New Jersey, on the north by such places as Titusville, Pennington, Lawrenceville, and Windsor, Mercer County; on the east by Lakewood, Lakehurst, and Bamber, Ocean County; and Green Bank, Burlington County; but occurrences very local and irregular east of Imlaystown, Monmouth County; New Egypt, Ocean County; and New Lisbon and Atsion, Burlington County; on the south by Nesco, Elwood, and Newtonville, Atlantic County; Malaga, Gloucester County; and Centerton, Shirley, Yorktown, and Pedricktown, Salem County. On the west, in Pennsylvania, the same area extended regularly as far as Pineville, Bucks County; Landsdale, Montgomery County; and Valley Forge, Chester County; and Wayne, Newton Square, Media, and Chester, Delaware County; near the latter being prolonged southward along the Delaware River as far as Claymont, in extreme northeastern New Castle County, Delaware.

In 1931 the limits of the general area of heavy infestation were extended northward, in New Jersey, to Stockton, Hunterdon County; Hopewell, Mercer County; Rocky Hill, Somerset County; Dayton, and Jamesburg, Middlesex County; and Englishtown, Monmouth County; eastward to Freehold, Monmouth County, Island Heights, and Brook-

[7]By obvious injury is meant foliage damage detectable without sensible effort from passing vehicle moving at a moderate rate of speed,—i. e., from 25 to 35 miles an hour.

ville, Ocean County; and New Gretna, Burlington County; but with occurrences quite sporadic in the Pine Barrens, especially their eastern half; southward to Egg Harbor City, Weymouth, and Mixpah, Atlantic County; Millville and Bridgeton, Cumberland County; and Cohansey, Penton, and Pennsville, Salem County. West of the Delaware River the same area advanced westward, in Pennsylvania, to Danboro and Line Lexington, Bucks County; Hatfield and Collegeville, Montgomery County; Phoenixville, Paoli, and Willistown, Chester County; and Gradyville, Wawa, and Twin Oaks, Delaware County; and extended southwest through northeastern New Castle County, Delaware, to the northern outskirts of the City of Wilmington.

In 1931 the linear distance from the original center near Riverton to the periphery of the area of heavy infestation varies according to direction, being greatest toward the east and least toward the west. Thus, the distance to Island Heights, the most eastern station of heavy infestation, is 46 miles, whereas that to Phoenixville, the farthest point west at which similar conditions obtained, is only 29 miles. Toward the north the greatest distance recorded is 30 miles, though this is increased northeastward to 40 miles. Southward the outermost point in the area of general heavy infestation is 42 miles from the original center, but this is decreased southwestward, in the direction of Wilmington, to 34 miles.

Those limited portions of the area of general heavy infestation which are shown on the maps as solid, or nearly solid, black patches are centers of unusually heavy, or maximum, infestation. In these centers the proportion of trees showing all, or a very considerable part of, their foliage riddled and discolored is definitely in excess of that typical of most of the heavily infested area. In the earlier years of the past decade damage of this now rather exceptional severity was general throughout all except the peripheral zone of the heavily infested area, but since 1925, with the continued expansion of the area, such sections of maximum infestation have exhibited a strong tendency to become locally segregated and to shift ever farther away from the original center until in 1930 and 1931 they occupied the positions shown on the maps. It will be observed that in these years the tracts of maximum infestation were located at points lying between the original center and the periphery of the general area of heavy infestation, and this is the same relative position which they have tended to maintain throughout their history. In other words, the areas of maximum infestation are not stationary, but continue to shift ever farther away from the original center as the general range expands. Thus it happens that many places which only a few years ago had not progressed beyond the initial stage of heavy infestation are

today far more heavily infested than are other localities which experienced their maximum infestation at a time when the present centers of maximum infestation were only lightly infested. Of course, in a single year the displacement of these centers is but slight, and on this account only a very limited amount of change in their positions is indicated on the maps.

If conditions were everywhere uniformly favorable, the areas of maximum infestation would presumably form an unbroken band or zone, surrounding the older infested areas and always shifting outward into the later infested ones. A few years ago, when the area heavily infested at the time was confined to the open country west of the New Jersey Pine Barrens, this condition was largely realized, but by 1930 the same area had already expanded eastward across the western margin of the Pine Barrens, where, as has been stated, definitely unfavorable conditions for the continued increase of the insect were encountered. The result was to break up the eastern limb of the zone of maximum heavy infestation, leaving, in New Jersey, two widely separated fragments, one toward the north, the other toward the southern edge of the general area of heavy infestation. Of these, the northern remnant, in 1930, formed a band extending diagonally across the open country of northwestern Burlington County, from Bordentown to Pemberton and Vincent town. In 1931 it had largely fragmented in its southern half, but farther north had shifted a few miles northeast, with its center at Allentown, Monmouth County. The southern remnant of the original zone, in 1930, centered about the boundary between Gloucester and Salem County. In 1931 it apparently changed its position only slightly, the infestation remaining at a maximum about such places as Elmer, Pittsgrove, and Woodstown, Salem County, but decreasing somewhat in the adjoining part of Gloucester County.

In Pennsylvania the area of maximum infestation has, for the most part, maintained its integrity, though there were indications of a temporary break in its continuity in 1930. In general, it formed a band a few miles wide in the west and southwest environs of Philadelphia and the adjoining parts of Bucks, Montgomery, and Delaware Counties. In 1931 its position changed but slightly, though there were apparent, in that year, a noticeable decrease in the infestation along its eastern and a concomitant increase about its western margin. At the present time the position of the areas of maximum infestation in Pennsylvania is indicated by the location of such places as Somerton, Philadelphia County; Newtown and Grenoble, Bucks County; Glenside, Spring House, Barren Hill, Plymouth Meeting, and Ardmore, Montgomery

County; and Radnor, Llanerch, Broomall, Lansdowne, Wallingford, and Ridley Park, Delaware County.

The remaining degrees of infestation represented in the area of continuous distribution call for no special consideration. All occur as transitional zones succeeding one another as the periphery is approached. As might be expected, considerable irregularity is witnessed in the New Jersey Pine Barrens, but otherwise the zonal arrangement of the different degrees of infestation is fairly regular, though eastward each zone tends to be considerably wider than in the opposite direction. Beyond the general area of heavy infestation, as previously delimited, succeeds a region of moderate infestation which at its periphery merges into the final zone of sparse infestation. In the former Japanese beetles are relatively frequent, but are only rarely sufficiently abundant to give rise to foliage injury readily detectable except at close quarters. Owing to the gradual way in which this area of moderate infestation merges into that of sparse infestation, no clearly defined line of demarkation can be drawn between them. In general, however, the practice is adopted of assigning to the area of moderate infestation all cases in which the number of beetles occurring at most points examined exceed ten and to that of sparse infestation those in which they fall below that number.

## TRAPS FOR THE ASIATIC GARDEN BEETLE[1]

By HAROLD C. HALLOCK,[2] *Associate Entomologist, Bureau of Entomology, U. S. Department of Agriculture*

ABSTRACT

Light traps and the geraniol trap are discussed in relation to the Asiatic garden beetle (*Autoserica castanea* Arrow). The geraniol trap has not proved successful. The history of the light trap is given, from the first one which caught 217 beetles in a season, to another which caught 21,000 beetles in a single favorable night. Such factors as wattage, kind of light, color of trap, shading of objects near trap, and temperature are discussed.

During the five years from 1927 to 1931, inclusive, several types of light trap and the geraniol trap, which had been developed in the Japanese beetle work, have been tested to determine their value in catching adults of the Asiatic garden beetle (*Autoserica castanea* Arrow).

[1]Contribution No. 94 Japanese and Asiatic Beetle Investigations, U. S. Bureau of Entomology, Moorestown, N. J.

[2]The data on geraniol traps from the Philadelphia area were gathered by I. M. Hadley and the writer desires to acknowledge permission to use this information in this paper.

GERANIOL TRAP. The geraniol trap[3] which had been used with great success in catching Japanese beetles, has been the least successful of those which have been tested against this insect. Nine of these traps, which were located for 43 days, from August 4 to September 16, 1931, in the Germantown section of Philadelphia, captured 40,134 Japanese beetles and 269 Asiatic garden beetles. The largest number of Asiatic garden beetles captured in any one trap was 64.

The Asiatic garden beetle is not so abundant in the vicinity of Philadelphia as in the northern part of Nassau County, N. Y., but it is sufficiently plentiful so that larger catches might be expected if the trap were effective. Several hundred beetles have been observed resting on each of a number of electric-light poles on warm nights over a large area in Philadelphia, and considerable feeding on foliage by the beetle has been observed at all the stations where the geraniol traps were placed.

Geraniol traps that were located near bright lights or close to plants upon which the beetles feed extensively caught more beetles than did those that were not so favorably placed.

HISTORY AND DEVELOPMENT OF LIGHT TRAPS. The first light trap, used in 1927, consisted of a lantern hung over a tub of kerosene. During the season this trap caught 217 Asiatic garden beetles. A 100-watt electric light was placed over another tub containing water with an inch film of kerosene, and in this trap 2,947 beetles were taken.

The following season (1928) a funnel trap was built. This trap (Pl. 17, Fig. 1), which was constructed of 30-gage galvanized iron, consisted of a funnel 4 feet in diameter at the top, 1½ inches at the bottom, and 3½ feet deep, and a can 12 inches in diameter and 2 feet high. A 500-watt electric daylight bulb was suspended above the center of the funnel. The bottom of the light was 5 inches above an imaginary plane connecting the outer edges of the funnel at the top and approximately 6 feet above the ground. In the early tests with this trap, soil was placed in the bottom of the can and the beetles were taken alive. As the beetles could be counted more quickly when dead, kerosene and water were later placed in the can to kill the beetles as soon as they entered the trap. In 1930 the can was replaced by a box with a door (Pl. 17, Fig. 2), and a pail containing water with an inch film of kerosene was placed beneath the funnel in order that the beetles could be removed more readily from the trap. This funnel trap, set up each year since 1928 at Westbury, N. Y., caught 188, 255 beetles in 1928, 107,686 beetles in 1929, 17,126 beetles in 1930, and 70,216 beetles in 1931. The largest catch in a single

[3]Van Leeuwen, E. R., and Metzger, F. W. 1930. Traps for the Japanese beetle. U. S. Dept. Agr. Circ. 130, 16 p., illus.

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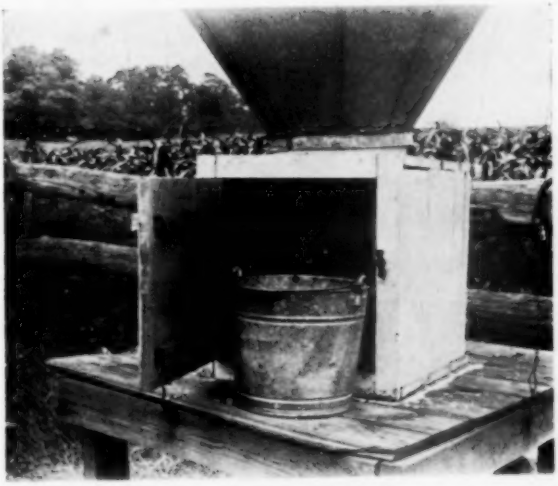
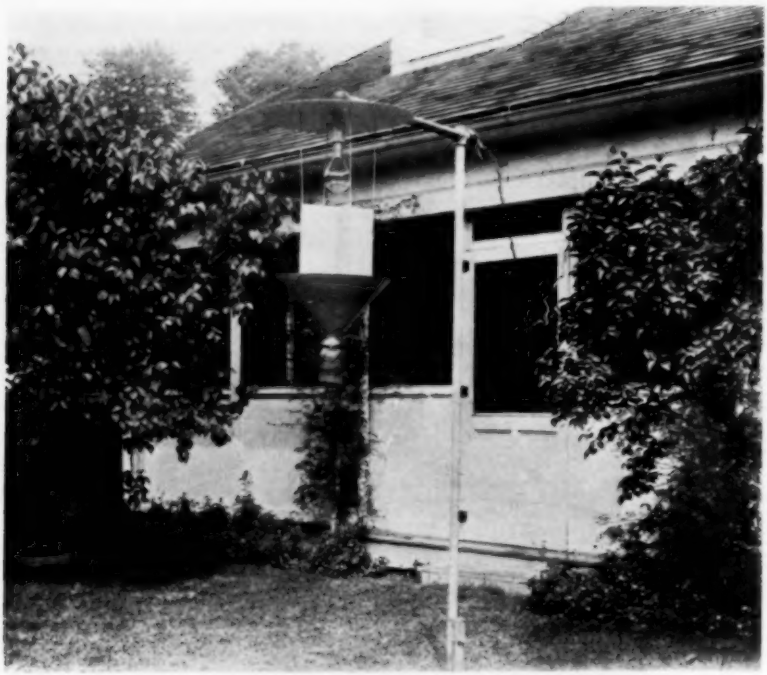


1.—Funnel trap for Asiatic garden beetle; 2.—Improved lower part of funnel trap

UNIV. OF MICH.



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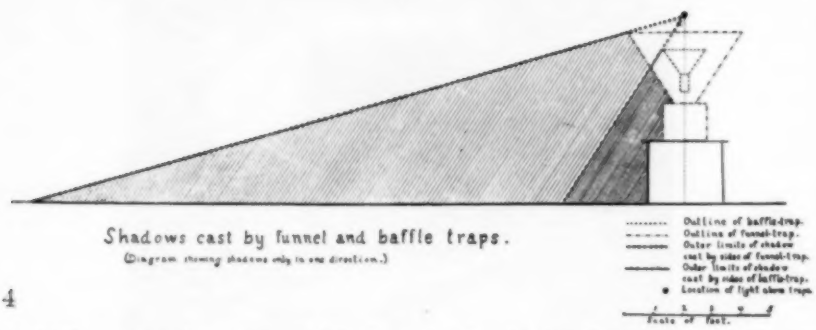
Shadows cast by funnel and baffle traps.
(Diagram showing shadows only in one direction.)
Outline of baffle-trap.
Outline of funnel-trap.
Outer limits of shadow cast by sides of funnel-trap.
Outer limits of shadow cast by sides of baffle-trap.
Location of light above traps.
Scale of feet.

4

3.—Baffle trap used to capture Asiatic garden beetle, 4.—Shadows cast by funnel and baffle traps

night was 21,012 in 1928, 11,600 in 1929, 2,362 in 1930, and 8,361 in 1931. As will be later explained, the smaller catch in later years is due to a reduction in the beetle population.

A trap designated as the pan-trap was tested in 1929. This trap, constructed of 30-gage galvanized iron, was 4 feet in diameter and 5 inches deep. The trap was painted white and contained about 3 inches of water with a half-inch kerosene film. A 500-watt daylight bulb was placed 5 inches above the pan and 6 feet above the ground. This trap caught 14,833 beetles in 1929. As this trap was less effective than the funnel trap, it was not again used.

In 1931 the baffle-funnel trap, which is generally called the baffle trap, was built and tested. The baffle and funnel are both constructed of 30-gage galvanized iron. The funnel is 18 inches in diameter at the top, ¼ inch at the bottom, and 12 inches deep. The baffle, which is 6 inches wide and 14 inches high, is made of two pieces of material fitted at right angles and soldered to the top of the funnel. The baffle is suspended by four 12-inch rods from a reflector 24 inches in diameter. A 500-watt daylight bulb is placed beneath the reflector and 14 inches from the top of the funnel. A fruit jar is fastened in the bottom of the funnel. The funnel, baffle, and reflector are painted with aluminum paint. The trap is suspended above the ground by an arm so that the light is 6 feet above the ground (Pl. 18, Fig. 3.) This trap caught 4,753 beetles in 1931.

Many people on Long Island have built traps similar to the funnel trap, but with more or less variation in design. The only improvement that has been observed is a funnel trap 4 feet in diameter at the top, 2 feet at the bottom, and 3½ feet deep. The pan containing the killing liquid is 3 feet in diameter and beetles which hit either the inside or outside of the funnel fell into the liquid in the pan. Records which were kept on one of these traps showed that 12,715 Asiatic garden beetles were caught in 1930. The efficiency of these traps was decreased by the failure to take into consideration one or more of the factors discussed in the following section.

Factors Which May Affect Efficiency of Light Traps. The study of traps from the time when first a lantern, then 100-watt, 300-watt, and 500-watt electric bulbs were used and observations upon the number of beetles collecting around electric lights of various powers up to 1,500 watts show conclusively that the brighter lights attract more beetles. It has also been determined that a 500-watt daylight bulb attracts more beetles than either clear or frosted bulbs of the same power. In ten minutes 235 beetles came to the trap when the daylight bulb was used

as compared with 99 for the clear glass. On another evening, when it was cooler, these electric lights were observed for 10 minutes with the following results: Daylight bulb 135, frosted bulb 110, and clear bulb 78 beetles.

As a result of preliminary tests, it is believed that the color of the trap will have a great deal to do with its efficiency. In order to obtain some data on this point, strips of tin 1 foot wide by 2 feet long were painted different colors and placed in a semicircle 4 feet from an electric light and counts were made of the beetles coming to each color during one-hour periods. The results are given in Table 1.

TABLE 1. REACTION OF THE ASIATIC GARDEN BEETLE TO COLORS

| Color | Number of Beetles Attracted | |
|---|---|---|
| | Trial 1 | Trial 2 |
| White | 576 | 666 |
| Yellow | 256 | 180 |
| Aluminum | — | 206 |
| Green | 186 | 104 |
| Red | 107 | — |

The light of the trap should be so placed as not to illuminate greatly shrubbery or other objects within a radius of 25 feet from the trap. The diameter of the funnel beneath the light should be sufficient to cast a shadow for about 20 to 25 feet and thus prevent the beetles from alighting on the vegetation near the trap. The relative efficiency of the funnel and baffle traps with respect to the shadow around them was determined by collecting and counting the beetles found on objects around the traps and by counting the beetles caught in the traps during the same period of time. It was found that only 25 per cent of the beetles attracted by the light were caught by the baffle trap, while 75 percent were caught by the funnel trap. The shadow cast by the funnel trap extended about five times as far from the base of the trap as did that cast by the baffle trap. (Pl. 18, Fig. 4.) The majority of the beetles collected around the baffle trap were found in the lighted area more than 4 feet and generally less than 20 feet from the trap.

In 1931 the two traps were tested in a place where the ground on one side was higher than on the other. (Pl. 17, Fig. 1.) When the baffle trap was used under this condition, the beetles were evenly distributed on the fence, plants, and other objects in the lighted area all about the trap, but when the funnel trap was used beetles were present only on the corn above the shadow.

Temperature is the most outstanding factor in connection with the flight of the beetles. During the past four summers the number of

nights when 1,000 or more beetles were caught was as follows: 30 nights in 1928, 26 nights in 1929, 5 nights in 1930, and 20 nights in 1931. It was noted that in 1929 the temperature was 70°F. or above on all of the 26 evenings when 1,000 or more beetles were caught. During 1930 and 1931 there were more nights when this temperature was reached, but the severe drought of 1929 and 1930 had reduced the beetle population to such an extent that the beetles were not flying in such large numbers as during earlier seasons. In a previous paper[4] this relation of the number of beetles caught in the funnel trap to temperature was discussed.

CONCLUSION. When the immense numbers of beetles taken in properly designed light traps are considered, it is believed that traps deserve serious consideration as a means of reducing beetle populations in heavily infested sections.

The light of the trap should not be allowed to shine brightly on objects near the trap, as many beetles will congregate on lighted objects instead of flying into the trap.

It is possible that the efficiency of the funnel-trap, which has caught the largest number of beetles, may be improved by increasing the steepness of the sides of the funnel, by placing a sufficiently large pan beneath the funnel to catch beetles striking the outside as well as the inside of the funnel and by painting the entire funnel with white enamel.

## Medical Entomology Notes

E. F. Knipling, Junior Entomologist, Bureau of Entomology, who has been engaged in Lamar, Colo., was temporarily transferred to Galesburg, Ill., on March 1.

Roy Melvin, Bureau of Entomology, who spent three months at Lamar, Colo., on cattle grub research, returned to Dallas, Tex., in February and has resumed his studies on the fly spray research project.

W. G. Bruce, Bureau of Entomology, left Florida on March 1 and arrived in Dallas, Tex., on March 4. He found cattle grubs still up in the backs of cattle at Tallahassee, and Pensacola, Fla., and through Louisiana and Texas. He observed heel fly activity at Pensacola on March 2.

[4]Hallock, H. C. 1930. Some observations upon the biology and control of Aserica castanea Arrow. Jour. Econ. Ent. 23: 281–286, illus.

# Scientific Notes

**Harmolita Species in Rye Grass.** The rye grass (Elymus) which grows in large patches on the hills of Contra Costa County, California, adjacent to the bay shore quite generally produces no heads, or at most only a few. This statement is based on observations covering a ten-year period. During the winter of 1928 I took occasion to "investigate." Many Harmolita galls were found in the unheaded stems near the surface of the ground. Galls placed in a breeding jar yielded three hymenopterous insects in the spring. These were identified by Mr. Gahan as *Harmolita elymophaga* B. & E., *Eurytoma pachyneuron* Gir. and *Eupelmus allynii* (French).

WYATT W. JONES, *Douglas, Arizona*

*Eucosma argentialbana* **Wlsm. as a Pest on Chrysanthemums.** In June, 1931, the writer examined a planting of hearty chrysanthemums near Denver and found most of the clumps heavily infested with a lepidopterous larva from ¼ to ¾ of an inch in length. Many of the clumps had died during the winter and others were in a weakened condition. The larvae seemed for the most part to be feeding upon the live tissue of the roots but in some of the clumps that had many dead roots they seemed to be doing equally well upon the dead tissue. The moths that emerged from the material during the latter part of June and the fore part of July, have just been determined by Mr. Carl Heinrich of the U. S. Bureau of Entomology, as *Eucosma argentialbana* Wlsm. This is of interest in that the food of this species does not seem to have been recorded, and the hosts of less than a dozen of the large number of species in this genus are known.

GEO. M. LIST, *Colorado Experiment Station, Fort Collins, Colorado*

**Control of the Red Spider Mite and the Citrus Mealybug on Greenhouse Plants.** One of the most promising insecticides for the control of both the red spider mite (*Tetranychus telarius* L.) and the citrus mealybug (*Pseudococcus citri* Risso) is a commercial product which analysis by the U. S. Food and Drug Administration has shown to contain 11.7 per cent of potassium soap, 2.1 per cent of potassium carbonate, 7 per cent of terpenes, and 79.2 per cent of water. As much as 95 per cent control of adult and immature red spider mites was obtained with one application of a 6.5 per cent dilution (1–16) of this material. Against the mealybug as high as 60 per cent of the adults and 95 per cent of the immature forms, as well as a considerable percentage of the eggs, were killed by one application of this insecticide at the same concentration. Plant tolerance to this spray was quite good. Two applications at an interval of one week produced no apparent injury to ageratum, Boston fern, calendula, chrysanthemum, coleus, cowpea, croton, cyclamen, nasturtium, pepper, and pachysandra. Snapdragons were very slightly injured; geranium and maidenhair fern were definitely injured but recovered.

HENRY H. RICHARDSON, *U. S. Bureau of Entomology, Washington, D. C.*

**An Observation of a Maggot,** *Rhagoletis pomonella* **Walsh, Passing from One Blueberry into an Adjacent Blueberry.** On August 18, 1930, two blueberries of slightly less than average size were observed clinging together. One was apparently normal, hard and fully formed; the other was a typical "maggoty" berry, its skin hanging in folds with a single hole visible, which was the point of insertion of the egg. When the two berries were separated slightly, a second hole was found in that area of the "maggoty" berry which had been in contact with the hard berry. The two berries, when

pulled, came apart, leaving a maggot of the late second instar with its anterior half within the hard berry. The hard berry showed no reddish digested contents, as was the case with the "maggoty" berry. After consuming the contents of one blueberry, apparently a maggot may leave its original host fruit, under favorable conditions, to eat its way into a second blueberry to complete its food requirements before pupation.

L. C. McALISTER, jr., *Bureau of Entomology, U. S. Department of Agriculture*

**The Apparent Incompatibility of Barium Fluosilicate and Nicotine Sulphate.** During a series of experiments for the control of the tobacco thrips (*Frankliniella fusca* Hinds) on shade-grown tobacco at Quincy, Fla., during the past season, nicotine sulphate was used. An infestation of the flea beetles, *Epitrix parvula* Fab. and *Epitrix cucumeris* Harr., also occurred at the time that the experiments against the thrips were being conducted. Since in another series of experiments a good control of the flea beetle was being obtained with barium fluosilicate, a combination of nicotine sulphate and barium fluosilicate was tested, the materials being mixed as follows: barium fluosilicate 1¼ pounds, nicotine sulphate 12 ounces, water 50 gallons. The mixture was applied to the crop at the rate of 100 gallons per acre immediately after mixing. Two days after the application very severe "burning" was observed on the buds and leaves of the tobacco plants. Later observations showed that the damage did not increase appreciably after this date.

At the same time a nicotine sulphate solution was being used over a considerable acreage of tobacco without any apparent "burning" and barium fluosilicate was being applied to other fields with only a slight trace of foliage injury, the latter material being used at the rate of 4 to 6 pounds per acre. It was, however, moistened by dew and light showers on several occasions.

It is evident from these observations that a combination spray of nicotine and barium fluosilicate is detrimental to tobacco foliage.

F. S. CHAMBERLIN, *Assistant Entomologist, U. S. Bureau of Entomology*

**An Observation on the Hibernation of the Corn Earworm in Maryland.** As is well known, the dry season of 1930 was exceptionally favorable for corn earworm development. In Maryland, especially in the lower Eastern Shore counties, severe damage resulted to sweet corn, tomatoes, and beans, particularly late bunch limas, which are planted for local canneries. It was thought advisable the following spring to determine the extent to which pupae were living over in the soil.

On March 21, 1931, with the aid of Dr. G. S. Langford, soil samples were taken in two fields near Berlin, one of which had been planted the preceding fall in tomatoes and the other in bunch lima beans. Neither of the fields had been disturbed since the crop had been harvested. The old bean and tomato stalks were standing. A square yard of soil to a depth of 10 to 12 inches was considered a sample. Samples were taken from several different parts of the fields.

In the bean five live noctuid pupae were found at the rate of 2.8 pupae per square yard or approximately 13,500 live pupae per acre. Dead pupae were found at the rate of 2.2 pupae per square yard or approximately 10,500 per acre. In the tomato field pupae were about one-third as numerous.

The live pupae were taken into the laboratory and the adults allowed to emerge. Of the emerging adults over 90 per cent proved to be *Chloridea obsoleta* Fab.

L. P. DITMAN, *University of Maryland Agricultural Experiment Station, College Park, Maryland*

**Introduction of *Eretmocerus serius* Silv. into Haiti.** After repeated attempts by the writer to rear out a native parasite of the Black Fly, *Aleurocanthus woglumi* Ashby, in Haiti had proved negative, negotiations were undertaken in March with the U. S. Bureau of Entomology and the Cuban Department of Agriculture to obtain a supply of its effective parasite, *Eretmocerus serius* Silvestri, from Cuba. This valuable parasite was introduced into Cuba in 1930 by Dr. C. P. Clausen from Malaya, through the cooperative effort of the two departments, and is now thoroughly colonized and established over the island of Cuba where a recent report shows 30 groves, previously heavily infested, as now being commercially clean. It has spread rapidly and in the controlled infestations examination of the pupae showed approximately 80% with parasite emergence holes. In July a shipment of citrus leaves was received by aeroplane from Havana through the kindness of Dr. Clausen. From this shipment approximately 150 living adults of the *Eretmocerus* were obtained and were released on two properties, well infested with *A. woglumi* on both citrus and coffee, at Petionville and Port-au-Prince, July 27–28, 1931. Following the suggestion of Dr. Clausen, the majority were liberated direct onto infested foliage but a number were released in the cellophane bags, placed on vertical branches, heavily infested, especially with the younger stages. A second shipment, received from Mr. P. A. Berry, yielded about 550 adult parasites that were liberated from August 14–16, 1931 on four other properties at Petionville, Turgeau, and Thor. This made six different points at which liberations were made and will serve as a source of supply for further distribution and natural spread. The parasites were observed to start ovipositing immediately in several different stages of the Black Fly and it is hoped and expected that the introduction will prove as highly successful in Haiti as in Cuba.

HERBERT L. DOZIER, *Chief Entomologist, Service Technique, Port-au-Prince, Haiti*

***Alysia ridibunda* Say, Parasitic on Blowfly Larvae.** From August 20 to September 4, 1931, 401 blowfly status jars were exposed for eight days at numerous points in western Texas, southern New Mexico, and Arizona. The term "status jar" refers to a narrow-mouth pint mason jar equipped with a four-mesh screen top. The bottom of the jar is covered with moist sand and on top of the sand are placed 4 ounces of lean beef for the purpose of inducing blowfly oviposition. These jars were returned to Uvalde, Texas, for a study of the emerging material.

A hymenopterous parasite, determined by Mr. C. F. W. Muesebeck, of the taxonomic unit, U. S. Bureau of Entomology, as *Alysia ridibunda* Say, emerged in jars which came from Las Cruces, Deming, and Socorro, New Mexico, and Duncan, Arizona. A total of 512 specimens emerged in 13 jars.

Mr. A. B. Gahan, in a letter of October 27, 1931, to Mr. F. C. Bishopp, reports that the Bureau's host-parasite index shows no published host record for this species. *Alysia ridibunda* was described by Say in Contributions Maclure Lyceum Philadelphia, Vol. 11, 1828, p. 77; Leconte Writ. Th. Say, Entom. Vol. 11, p. 380. Say's specimens were from Indiana and Provancher (1888) recorded the species from Canada. The distribution shown by identified material in the National collection is New York, Maryland, Virginia, Indiana, Illinois, Michigan, North Carolina, Florida, Kansas, Texas, and Arizona. The only host record shown by this material is that of the present series reared from blowfly parasite status jars collected in New Mexico and Arizona. They have since been bred from larvae of blowflies.

Mr. Gahan states further that the species is listed by Howard in his "Contribution to a Study of Fauna of Human Excrement," Proc. Wash. Acad. Science, Vol. 2, 1900,

p. 556, but no information about it is given. Nothing further seems to have been written about it.

A. W. LINDQUIST, *Junior Entomologist U. S. Bureau of Entomology, Uvalde, Texas*

**Pyrethrin Sprays in the Control of Greenhouse Pests.** Tests with sprays containing known concentrations of pyrethrins in combination with potassium oleate soap (0.25 per cent) indicated that such sprays, even with concentrations of pyrethrins as strong as 0.02 per cent (1–5,000), were unsuitable for the control of the citrus mealybug (*Pseudococcus citri* Risso) on coleus. These sprays apparently wet the plant and the insect very well, but only the very immature stages of this insect—that is, those individuals which had just emerged—were killed. With the greenhouse red spider mite (*Tetranychus telarius* L.) concentrations of the pyrethrins as high as 0.1 per cent, (1–1,000) were necessary in order to give commercial control (94 per cent).

Against the so-called sugar beet thrips (*Heliothrips femoralis* Reut.) a concentration of pyrethrins between 0.01 and 0.02 per cent (1–5,000 to 1–10,000) was necessary in order to give good control of adult and immature insects. The concentrations necessary to control aphids varied with the different species. The chrysanthemum and nasturtium aphids (*Macrosiphoniella sanborni* Gill. and *Aphis rumicis* L.) were easier to control than the green peach aphid (*Myzus persicae* Sulz.). A concentration of 0.01 per cent pyrethrins (1–10,000) with 0.25 per cent (1–400) soap gave complete control of the first two species, and approximately 60 to 70 per cent control of the last-named aphid.

Sowbugs very often become serious pests in greenhouses. There is need for a control measure which will not require the use of any substances poisonous to human beings (such as Paris green) or any process or method that will injure plants, roots, etc. (such as steam treatments). The pyrethrum-soap sprays present themselves as suitable insecticides and have been found to be quite toxic to sowbugs. A concentration of about 0.05 per cent pyrethrins (1–2,000) with 0.25 per cent soap was found to be suitable to give nearly 100 per cent mortality.

HENRY H. RICHARDSON, *U. S. Bureau of Entomology, Washington, D. C.*

**A Second Report on Burying Peach Drops to Prevent the Escape of Plum Curculio Adults.** Burying is still a method that is popular with southern peach growers for the disposition of peach drops to supplement the spraying or dusting for the control of the plum curculio (*Conotrachelus nenuphar* Hbst.) Growers have been undecided, however, as to how deep to bury these infested drops to make them harmless.

Our first report on an experiment to answer that question, which was published as a scientific note in the April, 1931, issue of the Journal of Economic Entomology, revealed the fact that curculio adults could emerge from drops buried 18 inches below the surface of the soil. The experiment was continued to determine just how far plum curculio adults could travel through soil after emerging from peach drops. The special boxes which were constructed for the 1930 experiments were used in 1931, except that the bottoms were removed and the boxes sunk 6 inches in the soil, so that maturing larvae would have facilities for pupating. One-half bushel of infested peach drops was placed in each box on May 12 and then covered with soil of depths from 18 to 36 inches. Adult emergence of *C. nenuphar* started on June 15,

and daily observations were made until 37 days after the last emergence. The results of this experiment are given in the following table:

| Box No. | Depth to which peach drops were buried (inches) | Curculio adult emergence Period | Number |
|---|---|---|---|
| 1 | Check (no soil on top) | June 15 to July 15 | 93 |
| 2 | 18 | June 19 to July 5 | 16 |
| 3 | 21 | June 19 to June 28 | 15 |
| 4 | 24 | June 24 to June 25 | 5 |
| 5 | 30 | June 25 to July 4 | 13 |
| 6 | 36 | June 25 to July 5 | 29 |

These results show that burying infested peach drops is not a safe method of disposal. Growers should make them harmless by submerging bags of them in large bodies of water, or by burning or boiling.

OLIVER I. SNAPP and J. R. THOMSON, *U. S. Peach Insect Laboratory, Fort Valley, Ga.*

**Bound Water.** In the October, 1931, issue of the Journal of Economic Entomology, a paper by F. S. Bodenheimer and Carl T. Schmidt, entitled "The Robinson Method for Determination of Bound and Free Water in the Insect Body," was published. The reason for the paper, the authors state, was to clarify for future workers the method used by Robinson for these determinations, which in their opinion was not explained clearly enough by Robinson himself. They therefore attempted to solve the difficulty by giving examples from some of their own determinations, carrying the figures throughout the development of the various stages in the equation involved. In case workers along this line should be misled by this publication, a few glaring errors will be pointed out which invalidate this "explanation" of Robinson's method.

(1) THE CORRECTION FACTOR: This is a coefficient introduced to correct for the amount of heat which the calorimeter itself supplies to the system in bringing the system to equilibrium. In calculating this factor, Bodenheimer and Schmidt took into consideration only the 80 calories per gram required to change ice at zero degrees Centigrade to water at zero degrees Centigrade, neglecting the fact that in the actual calculations, the free water is warmed from a temperature below zero, requiring approximately 0.502 calories per gram per degree, and after melting, is raised to a temperature close to room temperature, requiring one calorie per gram per degree. They state: "Since 80 calories are given off by one gram of melting ice,. . ." This is obviously wrong and should read: "Since 80 calories are required to melt one gram of ice at zero degrees Centigrade to water at zero degrees Centigrade,. . ." Not only these, but according to the example they gave, the water in the calorimeter gave off more heat than the ice could possibly absorb under the circumstances, even disregarding the fact that the calorimeter also gave up some of its heat.

Disregarding as they did, the number of calories required to raise the ice from its original temperature (below zero) up to zero, and from zero, after melting, up to the temperature of equilibrium in the calorimeter, this mistake was concealed by another. Their correction ratio is inverted, but since their denominator is wrong, they obtained a value similar to what it should be. The correction ratio should be expressed as:—

$$\frac{\text{Number of calories taken by the ice in warming from its original to final temp.}}{\text{Number of calories given off by the water to warm the ice.}}$$

Ideally, the numerator and denominator would be equal, but since the calorimeter supplies some of the heat used in warming the ice, the denominator will necessarily be the smaller quantity, and the ratio as given will correct for the heat taken from the calorimeter used. The denominator of Bodenheimer and Schmidt's ratio should be the numerator, and should be the larger quantity. The fact that they obtained a value similar to that given by the correct process is merely a coincidence.

(2) THE SPECIFIC HEAT OF THE INSECT: The method for finding the specific heat of the insect is given. It is a calorimetric determination involving the use of the correction factor discussed above. But in the example they use, the authors arrive at the astounding value for specific heat of Phyllophaga sp. of 1.22! Such a figure is ridiculous on the face of it, nor can it be explained by the error of the authors as regards the correction factor of the calorimeter.

Further work regarding the Robinson method for determining the free and bound water content of insects is being done by the authors.

R. W. SALT
E. H. HINMAN

**Indications of a Control Measure for *Tarsonemus pallidus* Banks on Strawberry.** Strawberry runner plants infested by *Tarsonemus pallidus* Banks (determined by Dr. H. E. Ewing) were exposed to a temperature of 110° F. in a saturated atmosphere for periods of one and a half hours and three hours to determine the effect on the mites and also the tolerance of the plants to the treatment. Vapor-sterilization apparatus as developed for the Mediterranean fruit fly treatment, in Florida, was used. The plants were in bundles of fifty plus, tied with a string, and tested thermometers were so inserted that the bulbs were in the centers of the bundles. The plants used were of the Mastodon variety, an everbearing type. The thermometers reached 110° F. two hours after the exposure started and the duration of the treatment was figured from that point; in other words, the one lot was removed three and one-half hours and the other five hours after the start of the experiment.

The plants were dug and bundled in the morning of October 29, 1930, and treated that afternoon. The following day one bundle representing each treatment period and also an untreated check of thirteen plants were planted in the U. S. Entomological Laboratory plots at Sumner, Wash. A space of 25 feet separated the treated and untreated plots.

Examination at planting time failed to disclose any live mites in either of the treated lots. Determination as to the condition of eggs could not definitely be made at that time.

Further examination at frequent intervals since has not shown any mites or eggs in leaf buds, leaves, blossoms, or fruit. All stages of the mites were found on the untreated plants at each examination, and the appearance of the treated plants throughout the season was a very definite further corroboration of the success of the treatment.

Since there was very slight growth throughout the winter months, it was not possible to distinguish any marked difference in top growth. On January 14, 1931, plants from each of the three plots were dug to see in what condition the roots might be. The roots of the plants from both treatments were decidedly inferior as compared with the roots of the untreated plants. Many of the roots had apparently been killed or badly injured by the treatment, such injury being sufficient to give the

impression that the treatment would not be satisfactory from the standpoint of plant tolerance. However, no plants were killed outright.

In the latter part of April blossoms appeared on the plants. Eleven of the thirteen untreated plants produced fairly numerous blooms, but the treated plants were distinctly different, as only five plants in each group showed any flowers. The treated plants, however, had a much better growth of foliage. In July the treated plants of both groups were blooming profusely, the leaf growth was excellent, and numerous runners had already appeared. Following this, fruit production of the treated groups has been more or less continuous and heavy and the fruit has been well shaped and free from the bronzing present on the fruit of the untreated plants. The mite infestation on the untreated plants has kept these in a very stunted condition and few runners have developed; the fruit produced was decidedly inferior in quality, most berries being small and misshapen, with considerable bronzing.

The behavior of the treated plants during the spring and summer has been so promising that further tests are planned to work out the details of this treatment as applied to strawberry plants infested with *Tarsonemus pallidus*.

C. F. DOUCETTE, *U. S. Entomological Laboratory, Sumner, Washington* and
WM. W. BAKER, *U. S. Entomological Laboratory, Puyallup, Washington*

**A New Pest in Greenhouse Grown Grape Stems.**—Several sections of grape stems were received January 13, 1932, from Oyster Bay, L. I., N. Y. They had a diameter of an inch and a half to two inches and showed a number of the typical galleries of ambrosia beetles. These were only about 1 mm. in diameter, and on cutting into one, an irregular cavity was disclosed, from which 35 insects were obtained. Subsequently, literally hundreds were reared from a series of stem sections with a total length of a little over three feet. The beetles are shining black or very dark brown, about a twelfth of an inch long, and present a general resemblance to the pear blight beetle, *Anisandrus dispar* Fabr. Specimens were kindly identified by Dr. Gilbert J. Arrow of the British Museum of Natural History as *Xyleborus germanus* Blandf., a species hitherto reported only from Japan, Korea and Formosa, and known to attack *Benzoin thunbergii*, *Carpinus laxiflora* and *Styrax japonicum*.

This record adds another to the list of species known to have been introduced from other countries and also a new plant host for this beetle. It is more than probable that this insect occurs in other woody, greenhouse plants in this country, especially as a number of related species are known to breed in a variety of hosts. The economic status of this new introduction cannot be determined at present. The insect, like its allies, is more likely to attack sickly or weak plants. Careful attention to these may prevent this ambrosia beetle causing serious injury.

E. P. FELT, *Director and Chief Entomologist, Bartlett Tree Research Laboratories, Stamford, Conn.*

## FIFTH INTERNATIONAL CONGRESS ON ENTOMOLOGY

Application blanks for membership and preliminary announcements for the International Congress of Entomology, which is to be held in Paris July 16–23, 1932, are being mailed to all members of the Society of Economic Entomologists, and the Entomological Society of America. Anyone interested and who is not a member of either Society, may obtain copies by writing to Professor R. Jeannel, Museum d'Histoire Naturelle, 45 rue de Buffon, Paris, 5, France, or to O. A. Johannsen. Cornell University, Ithaca, N. Y.

O. A. JOHANNSEN

# JOURNAL OF ECONOMIC ENTOMOLOGY

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The editors will thankfully receive news matter and other items likely to be of interest to our readers. Papers will be published as far as possible in the order of reception, except that papers of reasonable length may be accepted in the discretion of the editor for early publication at $3.00 per page. There is a charge of $3.00 per page for all matter in excess of six printed pages, a part page counting as a full page, this limit not including acceptance illustrations. Photo-engravings may be obtained by authors at cost.

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A. A. A. S. Winter meetings: 1932-33 Atlantic City; 1933-34 Boston; 1934-35 Pittsburgh; Summer meetings: 1932 Syracuse, 1933 Chicago, 1934 San Francisco.


The serious grasshopper conditions last year in the West-central and North-central States are likely to be duplicated the coming season unless conditions are correctly interpreted and plans made early enough to permit satisfactory handling of the situation. The experience of last year shows that widespread grasshopper outbreaks are still possible in the western area. It demonstrates the advisability of using the airplane in control work. It emphasizes the importance of timely distribution of the bait, and this not only relates to the seasonal conditions or the development of the insect, but is also closely dependent, if the best results are to be secured, upon a rapid distribution at certain hours of the day, provided temperature and weather conditions are favorable. This means that very rapid distribution is essential if satisfactory results are to be obtained. It also means that there must be an abundance of bait materials available at the time when they can be used to best advantage. Entomologists have been making surveys to determine probable developments the coming season. No better data are available for the guidance of farmers in the badly infested areas. It remains to be seen if the entomologists, in cooperation with leading agriculturists, can develop plans which will result in satisfactory control throughout most, if not all of the infested area. The economic entomologist of the present day cannot be entirely satisfied with predictions and then a statement later to the effect that the expected occurred. Real efficiency is prediction *and the adoption* of measures which will prevent serious losses. Can this be brought about?

# Reviews

**An Illustrated Synopsis of the Principal Larval Forms of the Order Coleoptera** by ADAM G. BOVING, Senior Entomologist, U. S. Bureau of Entomology and F. C. GRAIGHEAD, in charge of Forest Insect Investigations, U. S. Bureau of Entomology. Published by the Brooklyn Entomological Society, 1931, 8 vo., pp. 1–351, 125 plates.

This is a most comprehensive and much needed work on the larval forms of the Coleoptera. It gives a series of habitus-figures and detailed drawings of the typical larvae of the different families and subfamilies and presents keys for their determination.

The keys are linked with the drawings in such a way that it is easy for even the novice in the study of Coleopterous larvae to classify these forms. As a rule the arrangement agrees with that of the adults followed in the "Leng Catalogue," departures from it being mentioned in footnotes. One departure from the classification, followed by most authors, has been found in the study of the Cupesoidea larvae, "whose larval morphology isolates them from all other beetles;" for this reason the authors have recognized the suborder *Archostemata*, a term first proposed by Kolbe, for the families Cupedidae and Micromalthidae, noting that although these families are very specialized they are nevertheless so ancient that they must be regarded as an almost extinct type. The Archestomata placed at the head of the list is followed by Adephaga, the larvae of which "possess a complex of highly advanced and derivative characters which probably have been acquired through a long evolutionary period from an unknown primitive larval type somewhat different from the existing primitive Polyphaga larvae." The third and last suborder is the Polyphaga, the primitive type of which "is found in its most characteristic and original form in the series Staphylinoidea."

The discussion of the relation of the different families based on their larval characters is clearly presented in the introductory remarks followed in the main body of the paper by a synopsis of the three superfamilies and with an outline of the family series. The keys to the larval characters which follow are very clear and understandable and in every case where exceptions are found in the different series footnotes are given in which all of these exceptions are noted.

Any entomologist who is called upon to determine coleopterous larvae will find this publication an indispensable masterpiece of its kind and should feel grateful for the care and patience expended by the authors.

ANDREW J. MUTCHLER

**Die Forstinsekten Mitteleuropas** by K. ESCHERICH, Vol. III. Paul Parey. Berlin, 1931. 825 pages, 605 text figures, 14 colored plates.

This is the third volume of Escherich's work on the forest insects of Central Europe and includes part of the Lepidopteroidea (Panorpatae, Trichoptera, Microlepidoptera, Geometridae, and Noctuidae). Except for the first five pages, the text is devoted entirely to the lepidopterous families concerned. A fourth volume, in preparation, will include the remainder of the Lepidoptera, the Hymenoptera, Diptera and Hemiptera.

The section on Lepidoptera is divided into two parts, the first a general treatise on morphology and anatomy, life cycle, habits, importance to forestry, epidemiology, larval diseases, insecticide dusting, and systematics. The second part takes up the individual species of importance to the forests of that part of Europe. The material has been selected with care and presented in detail, and no phase of the problem appears neglected. In stressing the importance of lepidopterous forest pests it is pointed out that the greatest catastrophes of insect origin in the forests of Central Europe have been due to injury by caterpillars. These are primary pests of healthy stands, whereas beetles are in most cases secondary.

The author believes that the modern trend in forest entomology is in the study of outbreaks (epidemiology) and the factors causing these, and that great progress will be made in this field. The effect of the climate, site, type of stand, condition of trees, and so forth, is particularly emphasized. As an index of climatic effect the time-temperature hyperbolic curve is employed; that is, the duration of the development period times the effective temperature is considered a constant. The developmental potential under any climatic conditions may be thus calculated, and knowing this, the destructive quotient, that is, that proportion of the progeny which must be eliminated in order to maintain the population at a level, may be obtained. This leads, in a study of forest insects, to the necessity of watching the fluctuations in population levels in order to be able to anticipate an outbreak. The parasitic factor does not exert as great an influence as the other factors in the forest environment such as those above mentioned.

In discussing the individual species the author has spared no pains to present the available information in great detail, particularly as regards those forms which occur in devastating outbreaks. For example, the discussion of *Bupalus piniarius* occupies pages 463 to 569 and includes such subjects as the biology of the insect, the effect of environmental factors on its development, injuriousness, and distribution, its relation to forestry, methods of predicting the status of the population in regard to an outbreak, its control, its parasitic and predaceous enemies, and so forth. In treating the individual species the bioformula of Rhumbler is used, giving a very short and convenient mathematical expression of the life cycle. The colored plates illustrate adult and larval forms and injured forest stands, and the text figures are abundant. Both plates and figures are excellent. A list of the important members of each family of Lepidoptera and a key to these based on their food plants and larval injury precedes the discussion of the individual species. A bibliography accompanies each section of the text.

Although this work is devoted to the forest insects of Central Europe, the principles laid down and illustrated are applicable wherever trees grow, and the book will prove of inestimable value in its field. The author, whose reputation needs no comment here, has produced a very fine piece of work in every way.

ROGER B. FRIEND,
*Connecticut Agricultural Experiment Station*

## Current Notes

About February 1 Hugh E. Wallace and George T. York, Bureau of Entomology, were transferred from Riverside, Calif., to the Davis, Calif., laboratory.

Mr. James Marshall of the staff of the Dominion Entomological Laboratory, Annapolis Royal, N. S., has registered for the Ph.D. degree in Entomology at McGill University (Macdonald College).

The degree of Doctor of Philosophy was conferred upon George F. Knowlton, Associate Entomologist, of the Utah Agricultural Experiment Station, by the Ohio State University at its winter convocation in March.

Andre Audant who received his M.S. degree from the Kansas State College in July 1931 was appointed in October 1931 Chief of the Entomology Section of the recently established National Service of the Agricultural Production, located at Damien, Port-au-Prince, Haiti. He succeeded Dr. H. L. Dozier formerly in charge.

A conference with a group of peach growers from South Carolina was held at the Fort Valley Laboratory, Bureau of Entomology, on February 9 for the purpose of discussing the results of recent experiments. These growers came from Spartanburg, Florence, Manning, and Edmund, and included the president and field agent of the South Carolina Peach Growers Association.

Dr. C. B. Williams, lecturer in Entomology at the University of Edinburgh, has been appointed Professor of Entomology at the University of Minnesota for the spring quarter, 1932. During that time he will give a series of lectures in Advanced Economic Entomology. At the termination of this appointment Dr. Williams will return to England to become Chief of the Department of Entomology at Rothamsted Experiment Station, Harpenden, England.

The manuscript for a forest insect handbook for use of the field men for the Forest Service in Region 6 was completed by F. P. Keen, Portland, Oreg., during the month in cooperation with Mr. Jaenicke of the Forest Service. Only those insects of major importance in this region are considered, but these are described in full and each one illustrated with a full page plate. Methods of detecting outbreaks, reporting upon outbreaks and control methods are discussed in full and instructions given in regard to necessary reports by Rangers on forest insect activities. This field manual will be mimeographed and distributed to the Forest officers as a supplement to the Forest Management handbook.

The annual meeting of the North Central States Entomologists was held at Wooster, Ohio, March 3–4, 1932. This group does not permit the presentation of formal papers, but titles for discussion are suggested by various members and sone one in the group is then appointed to open the discussion. Each topic is thus presented for a round table discussion. In conjunction with these meetings the National Codling Moth and Oriental fruit moth conferences were held on March 2 and the Central States Plant Board meeting was held on March 4 and March 5. About 125 members from several states and the federal Bureau attended the meetings and decided interest was shown in the discussions.

Announcement was made February 26 that Mr. William H. White, entomologist Truck Crop Insect Investigations, Washington, D. C., was promoted to Principal

Entomologist and appointed as leader of the Division of Truck Crop and Garden Insects. Mr. White graduated from the Maryland Agricultural College in 1913 with the B.S. degree and was associated with the Maryland Experiment Station the following year. Since 1914 he has been associated with the Bureau of Entomology in the Truck Crop Insect Office at Washington with the exception of the year 1918–1919 when he was an officer in the U. S. Infantry. Mr. White has been acting in charge since the resignation of J. E. Graf in March 1931. Mr. White is therefore especially qualified to direct the investigations of this division.

Miss Esther Hastings Hart, Illustrator in the Bureau of Entomology, retired from the service on February 29 after 23 years' work in the Government. Miss Hart is a daughter of the late Dr. Ira Hart of Elmira, N. Y. She holds the degree of Bachelor of Arts from Elmira College, N. Y., and also took a four years' course in wood engraving at Cooper Institute, New York City, where she was associated with Mrs. Anna Botsford Comstock. Her first work in the Government was that of topographical draftsman in the U. S. Forest Service. She has served as artist in the Bureau of Entomology since 1911. She is a member of the Biological Society of Washington, the American Association of University Women, and the Washington Art and Archaeological Society. Her associates in the Division of Cereal and Forage Insects, gave her a luncheon on February 20 at the Shoreham Hotel and on February 25 a purse of gold was presented to her by about 140 of her colleagues and friends throughout the Bureau in Washington and in the field.

## Horticultural Inspection Notes

The list of plants subject to terminal parcel post inspection in Mississippi has recently been reduced to include only sweet potato plants, vines, and cuttings, and morning-glory vines and roots.

The State Plant Board of Arkansas has declared a quarantine on account of the black walnut canker (*Nectria galligena* Bresadola), prohibiting the entry of black walnut plants from Virginia, West Virginia, and Pennsylvania. This quarantine (No. 9) was issued on September 4, 1931.

Further amendments to the Arizona quarantine on account of the alfalfa weevil provide that fruits, grains, vegetables, and nursery stock may now enter the State from the infested areas, under special certification. These amendments became effective on January 1, 1932.

Among the State inspectors cooperating with the Federal Department of Agriculture on transit inspection this spring are Mr. Rogers, Knoxville, Tenn.; Charles Denny, St. Louis, Mo.; J. Carl Dawson, Kansas City, Mo.; V. F. Peterson, St. Paul, Minn.; A. L. Piller, Milwaukee, Wis.; H. F. Seifert, W. R. Jack, and J. S. Conard, Chicago, Ill., and D. L. Wray, Hamlet, N. C.

The Texas State Department of Agriculture announces that "an important disease of onions known as Pink Root, which is caused by a fungus (*Fusarium malli*), is known to occur in the South Texas onion district." A quarantine (No. 63) was proclaimed effective on March 10, 1932, restricting the intrastate movement of onion plants from the infected area.

The Arizona quarantine relating to the grape mealybug (*Pseudococcus maritimus*) and grape phylloxera (*Phylloxera vastatrix* Planchon) which formerly prohibited the entry of rooted grapevines from California, was revised on December 15, 1931, to permit the entry of rooted grapevines, after hot water treatment. The revision provides that grape cuttings may continue to enter when so treated.

Because of the prevalence of virus diseases of the genus Rubus and of the loganberry, dewberry, and blackberry, the Oregon State Department of Agriculture established a quarantine (No. 23) on February 23, 1932, prohibiting the entry of these plants from all parts of the United States, except California, Arizona, and New Mexico. Provision is made for bringing in desirable varieties under special permit for trial plots.

The Federal pink bollworm quarantine regulations were revised effective February 1, authorizing the issuance of permits for the interstate movement of cottonseed from certain lightly infested sections of the pink bollworm infested areas, on condition that the seed is heated to 145° F. for one hour under Federal supervision. Heretofore the interstate shipment of cottonseed from all parts of the regulated areas to outside points has been entirely prohibited for a number of years.

A cedar eradication project for the protection of apple orchards has been undertaken in southeastern Nebraska. The activities involve the territory within two miles of orchards of 1,000 trees or more and will be confined largely to Richardson, Nemaha, Otoe and Cass counties which are located along the Missouri river. Under a Nebraska law passed in 1929 and amended in 1931, cedar trees growing in the vicinity of apple orchards are declared nuisances and may be ordered destroyed by the State Department of Agriculture.

The European corn borer quarantine regulations were amended by Secretary Hyde, effective February 5, 1932, adding considerable territory to both the one-generation and two-generation regulated areas and transferring parts of Connecticut, Massachusetts, New York and New Jersey from the one-generation regulated area to the two-generation regulated area. Modifications were also made in the certification requirements for young chrysanthemum, aster, and dahlia plants.

The freezing of green corn on the cob was authorized by the Plant Quarantine and Control Administration as a condition of certification under the European corn borer quarantine regulations on February 3. In order to secure such certification, the corn must be subjected to freezing temperatures and, after it is frozen, it is to be cooled until it is at or below a temperature of 0° F.; it is then held at or below that temperature for a period of eight days from the time all the corn in each part of the package reaches that temperature. The order was issued as PQCA-328.

Texas State citrus quarantines Nos. 29, 31, 32, 33, 34, and 37, relating to the entry of citrus fruits from Florida, Louisiana, Mississippi, and Alabama on account of various diseases and insects, have been amended by Proclamation No. 59, effective February 25, 1932, to provide for the entry of these fruits into the northern or non-citrus area of the State, under certain packing and marking requirements. The department states that "the eradication or control of these diseases and insects in the respective States in which they are known to occur has been carried on very effectively during the past few years."

On March 24 to 28, four hearings to consider the status and possible discontinuance of four important Federal plant quarantines were held at Washington, D. C., on order of Secretary Hyde. The quarantines involved were those relating to the European corn borer, the Japanese beetle, the white pine blister rust, and narcissus bulbs. In connection with the announcement of the hearing, Mr. Lee A. Strong, Chief of the Plant Quarantine and Control Administration said: "The conference will consider whether or not the investigation of control methods, parasites, and resistant varieties has reached the stage where Federal quarantines on interstate movement of plants should be removed; whether the spread of the diseases and pests has been so wide as to make Federal control undesirable and inexpedient; and whether the States which are threatened by these pests and diseases are able to fight them as efficiently and economically as the Federal authorities can do it."

Because of the recent discovery of the citrus white fly (*Dialeurodes citri*, Ashm.) in Los Angeles County, Calif., the State Department of Agriculture revised the intrastate quarantine (No. 11) on March 10, 1932, to include a part of that county in the regulated territory. A reduction in the area under regulation in Sacramento County was recently made, to include only the city of Sacramento. Parts of four other counties are under regulation at present, viz., Yuba, Sutter, Butte, and Orange.

The Federal Mexican fruit worm quarantine was amended effective March 5 to require the sterilization of host fruits produced in Cameron, Hidalgo and Willacy Counties, Texas, before they may be moved to points in the States of Alabama, Arizona, Arkansas, California, Georgia, Florida, Louisiana, Mississippi, Nevada, New Mexico, North Carolina, Oklahoma, Oregon, South Carolina, Tennessee, or Washington. The Department of Agriculture in announcing the change, reported that light infestations have recently been found in the regulated area of Texas, and that such infestations are being cleaned up promptly but that the limitation of movement has been deemed advisable as an aid in protecting localities thought to be most susceptible to Mexican fruit worm infestation. Supplementing the amendment, two circulars (PQCA-329 and -330) were issued, prescribing methods of treating grapefruit and oranges by heat and by cold, respectively. The required sterilization is done under the supervision of representatives of the Plant Quarantine and Control Administration.

The 8th annual meeting of the Central Plant Board was held at Wooster, Ohio, on March 4. Representatives were present from Kansas, Missouri, Minnesota, Wisconsin, Illinois, Indiana, Kentucky, and Ohio. The subjects discussed included the hearings announced by the Federal Department of Agriculture for the consideration of the European corn borer, Japanese beetle, white pine blister rust, and narcissus bulb quarantines. Resolutions were passed favoring the retention of the Japanese beetle and white pine blister rust quarantines and the discontinuance of the domestic narcissus bulb quarantine. The resolution relating to the European corn borer quarantine read as follows: "Be it also resolved, That since Congress has failed to comply with the request of the Secretary of Agriculture to appropriate adequate funds to maintain an efficient European corn borer quarantine that the Central Plant Board go on record as not favoring the expenditure of funds on an inefficient quarantine such as a paper quarantine would be." Mr. H. B. Hungerford was elected president and Mr. P. T. Ulman secretary. It was decided to hold the next meeting at St. Louis, Mo., during the first week of March, 1933.

Several modifications have been made in Florida State plant quarantines, according to an announcement of the State Plant Board in a special bulletin dated February 17, 1932, quoted in part as follows: "A number of the State regulations which have heretofore been somewhat in conflict with Federal regulations covering the same subject matter have been so revised as to bring them into conformity with the quarantine requirements of the Plant Quarantine and Control Administration, United States Department of Agriculture, as applying to both domestic and foreign subjects. A new rule has been adopted covering the intrastate movement of peach and nectarine stock. This rule parallels the Federal quarantine on phony peach disease." Other changes in Florida rules were adopted on January 11, 1932 as follows: Rule 37, prohibiting the entry of banana plants or bulbs and of coconut trees, plants, or nuts, and Rule 39, prohibiting the entry of tung oil seed and trees from foreign countries, were repealed. Rules 47A and 47B relating to the West Indian fruit fly were adopted and have the effect of prohibiting the movement of host fruits of the fly out of Monroe County, Fla., and of providing for the transportation, under proper safeguards, of host fruits imported under the provisions of Federal Quarantine No. 56, through the above county to points outside. Rule 30 relating to the brown rot disease of citrus was repealed and a new rule adopted permitting the entry of California lemons and oranges under certain safeguards.

## Apiculture Notes

Jas. I. Hambleton attended the annual meeting of the Southern Beekeepers' Conference at St. Petersburg, Fla. Beekeeping leaders of the various Southern States were well represented at this meeting. Mr. Hambleton also acted as one of the judges of the bee and honey exhibit at the Florida State Fair at Tampa.

Wilmon Newell, director of the Florida State Plant Board, and M. S. Yeomans, state entomologist, Atlanta, Ga., were consulted by Mr. Hambleton for the purpose of drawing up plans for cooperative work on the new disease of the brood of bees which has recently made its appearance on the Florida-Georgia border.

Jas. I. Hambleton, in charge of the Bee Culture Laboratory, Somerset, Md., held two conferences in February with C. F. Snyder and L. D. Hammond, of the Bureau of Standards, relative to questions arising in the research on the density of honey. F. J. Bates and S. T. Phelps of the same Bureau were also consulted for confirmation of the finding of anhydrate dextrose crystals in a sample of honey.

On February 25 Mr. Landau, the local representative of the Mountain States Honey Cooperators, called at the Bureau of Entomology Bee Culture Laboratory relative to the melting up of 800 shipping cases of comb honey which had granulated. In addition to the honey obtained, the wax is of a fine quality and light in color, and, if produced in blocks and free of honey, 30 cents a pound can be obtained for it. In order to advise him adequately as to the best method of handling the wax, a visit was made to Mr. Landau's place of business.

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ERRATA

*Eulia mariana* is the species illustrated on Plate 50. Fig. 2, Journal of Economic Entomology, Vol. 24, No. 6, and not *Stenoma algidella* Walk., as published.